29

ANIMAL HUSBANDRY MANUALS

DAIRYING IN INDIA

BY

JAMES N. WARNER, M.Sc.

The Allahabad Agricultural Institute, Allahabad (U.P.)

Issued by the Indian Council of Agricultural Research

MACMILLAN AND CO. LIMITED

CALCUTTA BOMBAY MADRAS LONDON

1953

DAIRYING IN INDIA

This book is copyright in all the countries which are signatories to the Berne Convention.

First Edition 1951
Reprinted 1953

MADE IN INDIA

PRINTED BY B. PAGE, AT THE I. S. S. D. PRESS,
95 B, CHITTARANJAN AVENUE, CALCUTTA.

FOREWORD

This is a second of a series of manuals to be prepared for the Indian Council of Agricultural Research on subjects relating to animal husbandry. It appears at a time when there is obviously a stirring of public conscience concerning the nutritional state of the masses and, one hopes, it denotes the ultimate awakening to the fact that without methodical effort and the utilisation of modern methods the milk resources of the country cannot be effectively drawn upon. That every drop of milk that can be obtained in India should be utilised in the most economic manner is now appreciated by all those who realise what a gap exists between the country's needs and her resources. This manual will guide those who are making the attempt to bridge that gap.

The Indian Council of Agricultural Research has indeed been fortunate in obtaining an author who, having been grounded in modern dairy technique and the practical management of dairy stock in a country whose methods are a model of progress, has studied the milk requirements of India both in the village and the town, has assessed the potentialities and the limitations of its livestock and resources, and has been able to select and put into the manual what it is necessary that all those engaged in the practice or the study of the science of dairying in India should know.

GRAHAME WILLIAMSON,
Animal Husbandry Commissioner with the Government of India.

Delhi, 1945.

INTRODUCTION

The cow and her products have an importance in India far beyond that in most countries. The dairy industry, through which the cow provides our people the equivalent of about six ounces of milk per person per day in the form of milk and milk products, is one of the largest and most popular—yet most mismanaged—industries in India. The scientists, however, have given surprisingly little attention to it. No industry needs the scientific approach more than the dairy industry in India. It is, therefore, commendable on the part of the Indian Council of Agricultural Research that it is doing something to meet this need by arranging for a factual monograph on Indian dairying.

Few men are better qualified to write such a treatise than Mr. James N. Warner. The Indian literature on the subject is meagre. This useful work should prove of value to all who are interested in dairying, especially students and teachers in agricultural colleges, field workers and those engaged in the dairy business. In so far as this volume stimulates an interest in the subject which leads to larger supplies of clean and safe milk being made available to our people, just so far is it a contribution of the first magnitude to the welfare of India. One fact suffices. Life expectancy and milk consumption are related. Those nations consuming the largest amounts of milk have the greatest expectancy of life, while those milk-consuming nations which utilize the smallest per capita amount of milk have the lowest expectancy of life. No excuse is needed, therefore, for so useful a work on so important a subject.

I wish the volume the wide study it unquestionably deserves.

SAM HIGGINBOTTOM.

PREFACE

This book was written for the student and the field worker; consequently it has two purposes to fulfil, that of a college text book and that of a field manual. In the first case it was necessary to include detailed explanations of certain elementary subjects for the benefit of those whose practical experience, in most cases, is extremely limited. In the second, many statements and discussions pre-suppose a knowledge of certain fundamentals on the part of the reader. If it meets either need, the tremendous amount of time and energy expended in its preparation will have been justified. There is reason to hope that it may be worthwhile for there are very few texts which have been written on the subject of dairying in India. Dairying here is different in many ways from what it is in other important dairy countries.

Such a book would have been impossible without help from publishers, authors, organizations, colleagues and assistants. Publishers and authors whose works are referred to specifically are listed in the bibliography at the end of the text. The ideas of many others have influenced the thoughts of the writer and are, consequently, included in one way or another. The book was written at the request of and with the help of a grant from the Indian Council of Agricultural Research. The Allahabad Agricultural Institute permitted the author to undertake to write the book and allowed him sufficient time from his other duties to do so. Major G. Williamson read the chapters as they were prepared and made innumerable criticisms and recommendations which greatly improved their content. Dr. F. C. Minett helped considerably in the preparation of Chapter

VI by his welcome suggestions. Dr. Sam Higginbottom read most of the chapters and helped considerably with his suggestions. Dr. T. W. Millen helped at every opportunity, particularly with his advice on several parts of Chapter II. Mr. N. R. Joshi gave freely from his experience of many years as a teacher and a student; Appendices V and VI were contributed entirely by him. Mr. Adin P. Brooks suggested the idea of the table in Chapter IV on the Formation of Milk Products and assisted in its preparation. Mr. S. R. Biswas spent several months assisting the author by reading and abstracting the literature from India and abroad from which a large portion of the material included in the text was taken. Mr. H. L. Mehrotra assisted in the same capacity for a short time. Mr. K. C. Chacko and Mr. Bhagwati Prasad, steno-typists, were responsible for all the dictation and typing work involved. The author takes this opportunity to acknowldge this help and to extend his sincere appreciation for it.

If the book were to be dedicated it would be to India's mothers and their babies. Their need for adequate food of the right kind is one of the most pressing needs the world has ever known. Adequate milk and milk products, available at prices everyone could afford to pay, would contribute as much, or more, than any other group of foods toward meeting this need. If the book contributes in any way to the meeting of this need the author will feel that one of his obligations to mankind has been partially fulfilled.

The Allahabad Agricultural Institute,
American Presbyterian Mission,
Allahabad, U. P.
May, 1945.

JAMES N. WARNER.

CONTENTS

		Page
Foreword	.. ..	v
Introduction	.. ..	vi
Preface	.. ..	vii
Chapter I	Dairy Farming and its Relation to Agriculture .. Cattle labour; milk; manure.	1
Chapter II	The Management of Dairy Cattle in Health and Disease .. .. The calf; the young animal; the pregnant animal; the heifer or cow at parturition; the milking animal; the dry animal; the bull.	11
Chapter III	Milk Secretion .. .. Number and location of the mammary glands; physical development of the udder; hormones and milk secretion; nervous control in milk secretion; precursors of the constituents of milk; rate of secretion and capacity of the udder; rapidity and number of milkings.	36
Chapter IV	The Constituents of Milk and its Nutritive Value .. Milk from different mammals as human food; the composition of milk; the nutritive properties of milk constituents; the	51

		Page
	effect of heat on milk; the nutritive value of milk and milk products.	
Chapter V	Dairy Chemistry .. .. Determination of the percentage of fat by the Gerber method; determination of the specific gravity of milk; determination of the total solids of milk; determination of the titratable acidity of milk and milk products; determination of the freezing point of milk; the chemistry of chlorine sterilization; heat coagulation point of milk and factors affecting it; crystallization; neutralization of cream; chemical analysis of butter; Kohman procedure for butter analysis; analysis of ghee; milk and metals.	75
Chapter VI	Dairy Bacteriology .. Methods of reproduction; bacteriological terminology; the occurrence of bacteria; the growth phases of bacteria; bacteria in milk; the action of micro-organisms in milk; the bactericidal action of milk; bacteria and milk products; acids of bacterial origin as food preservatives; preserving milk and milk products by refrigeration;	104

PAGE

methods of counting bacteria.

CHAPTER VII — DAIRY ENGINEERING .. 127
Milking barns; milk house; calving stalls; feed store and silos; sheds; fences; feed grinders and chaffers; the milk plant or creamery; washroom equipment; steam boilers; pasteurizers; cream separator; cold store rooms; coolers; cans and pills; scales and balances; churns; milk bottles, bottle fillers and bottle cappers.

CHAPTER VIII — COMMON DAIRY PROCESSES .. 157
Heating and cooling; regenerative heating and cooling; agitation; aeration; coagulation; straining and filtering; the separation of milk; clarification; homogenization; washing; chemical sterilization.

CHAPTER IX — *Dahí*, GHEE AND BUTTER .. 196

CHAPTER X — *Khoá*, *Khír*, *Sár*, *Maláí*, *Rabaṛí*, *Chhená* AND SWEETS 219

CHAPTER XI — CASEIN, CHEESE, ICE CREAM, *Kulafí*, EVAPORATED AND CONDENSED MILK AND DRIED MILK 232

CHAPTER XII — PRODUCTION RECORDS .. 251
Quantity of milk and butter fat test both required; reasons for maintaining production records; demands

PAGE

for food energy in the dairy cow; heat energy conversion as a measure of utility; production and supplementary records; milk recording in India; the lactation curve; equipment required; outstanding production records.

CHAPTER XIII THE ECONOMICS OF DAIRYING AND DAIRY BOOKKEEPING .. 273
The dairy business; the cost of milk production; dairy bookkeeping; double-entry bookkeeping; further suggestions.

CHAPTER XIV MARKETING OF MILK AND CO-OPERATIVE DAIRYING .. 300
Quality of milk; special problems; transportation of milk; marketing milk; co-operative dairying.

CHAPTER XV GOATS AND OTHER ANIMALS AS MILK PRODUCERS 323
Goat; sheep; camel; ass.

APPENDICES 328

BIBLIOGRAPHY 351

INDICES 360

CHAPTER I

DAIRY FARMING AND ITS RELATION TO AGRICULTURE

India is an agricultural country in which between 85 and 90 per cent of the people, numbering close to 400,000,000, live in rural areas. One of the major aspects of the economy of our rural people is the importance of the zebu (*Bos indicus*) and the buffalo (*Bos bubalus*) as producers of draught power and of milk. Lord Linlithgow, former Viceroy of India, explained this very clearly by saying, 'The cow and the working bullock bear on their patient backs the whole structure of Indian agriculture.'

The livestock census of 1940 (27)* indicates a bovine population in India of 207,850,737 consisting of zebus and buffaloes distributed between "British India and the Indian states", according to age and sex, as follows:—

		ZEBU	BUFFALO
British India—			
Males over 3 years	..	46,777,123	4,910,540
Females over 3 years	..	36,379,892	15,126,587
Young stock	..	32,178,304	12,050,661
Total	..	115,335,319	32,087,788
Indian states—			
Males over 3 years	..	17,002,221	1,370,376
Females over 3 years	..	15,889,362	6,760,983
Young stock	..	14,191,025	5,213,663
Total	..	47,082,608	13,345,022
Total for India	..	162,417,927	45,432,810
Grand Total	..	207,850,737	

The Indian Council of Agricultural Research recognizes 31 breeds of zebus and eight breeds of buffaloes (76 and 108).

*Unless otherwise stated, figures in brackets refer to references at the end of the book.

These breeds and the areas in which they are most common are indicated in the following table:—

Breed	*Home area*
ZEBU	
Alambadi	Coimbatore and Salem District of Madras and Mysore
Amritmahal	Mysore
Bachaur	Bihar
Bargur	Coimbatore
Bhagnari	Baluchistan and Sind
Dangi	Bombay
Deoni	Hyderabad State
Dhanni	Punjab
Gaolao	Central Provinces
Gir	Kathiawar
Hallikar	Mysore
Hariana	Punjab and Delhi
Hissar	Punjab (Hissar Dist.)
Kangayam	Madras (S. & S. E. Coimbatore)
Kankrej	Kutch, Kathiawar and Gujerat
Kenwariya (Kankatha)	United Provinces and adjacent states of C.I.
Kherigarh	United Provinces
Khillari	Bombay
Krishna Valley	Bombay and Hyderabad State
Lohani	Baluchistan and North-West Frontier Province
Malvi	Central India
Mewati (Kosi)	Alwar and Bharatpur States and U.P.
Nagori	Jodhpur
Nimari	Bombay (Narbada River valley)
Ongole	Madras
Ponwar	United Provinces
Rath	Alwar State
Red Sindhi	Sind and Baluchistan
Sahiwal	Punjab
Siri	Sikkim, Bhutan and N. Bengal
Tharparkar (Thari)	Sind
BUFFALO	
Jaffarbadi	Kathiawar
Kundhi	Sind
Mehsana	Baroda
Murrah	Punjab and Delhi
Nagpur or Ellichpur	Central and South India
Nili	Punjab
Ravi	Ravi River valley
Surti	Bombay and Baroda

A few of the breeds of zebus listed here are usually called milk breeds, as distinct from those which not only produce milk in fairly large quantities but are well known for their draught purposes. The milk breeds are the Red Sindhi, Sahiwal, Gir and Deoni, of which the first three are most widely known. The Tharparkar, Kankrej, Hariana and Ongole are known to produce reasonably large quantities of milk when properly cared for and are, particularly the Tharparkar and the Hariana, sometimes considered good dual purpose breeds. The remaining breeds are of value principally for draught purposes.

Macgregor (63) divides the domestic buffalo into the river and the swamp types. Those found in India, largely of the river type, are used primarily for milk production, although the male is frequently used as a draught animal, especially for carting work and rice cultivation. Macgregor says that the swamp type, found in large numbers in the Malaya peninsula, is better for rice cultivation because it does not step on the bunds between the fields as the river type does.

Figures showing the comparative importance of the different aspects of our agricultural economy are not easily obtained; furthermore, prices change from time to time, particularly during the past few years, so that any comparison soon becomes out of date. Dr. Wright (113), however, gives some information which is of use in this connection, although he refers to pre-war conditions which, particularly so far as the value of the different items in terms of rupees is concerned, are not accurate at the present. According to Wright, who partially quotes other authorities, the values of the products and services provided annually by our cattle are as follows:—

1.	Cattle labour	Rs. 400 crores.
2.	Milk	300 ,,
3.	Cattle manure	270 ,,
4.	Live cattle exported	0·05 ,,

To these figures may be added certain others, such as

5.	Meat	15·5* ,,
6.	Bones	7* ,,
7.	Hides	6(17) ,,

**Estimated*

Dr. Wright points out that the "total value of India's output of agricultural produce varied as follows: Rs. 1,983 crores in 1922, Rs. 3,400 crores in 1929 and Rs. 2,000 crores in 1936." The importance of cattle, as of the milk they produce, in our agricultural economy is obvious. Milk alone is worth approximately one-seventh of the total.

Cattle Labour

The zebu is much more important as a draught animal than the buffalo and there are 3·6 times as many of them in India. We have 162,417,927 zebus and 45,432,810 baffaloes. The buffalo, on the other hand, is the more important producer of milk, as will be mentioned later.

The human population of this country has increased about 100,000,000 in the past 50 years. As the population increases the number of farm holdings increases while the average size of these holdings decreases. This tendency is only partly offset by the very small increases that have taken place in the area under cultivation. The nature of our inheritance laws and the fact that only a very small proportion, if any, of the increase in our rural population is absorbed by expanding industries help to account for these facts. There is a very great tendency on the part of the village farmer to operate his holding as a unit regardless of its size. In this connection, he does not readily share his bullocks or implements with other farmers; he chooses to be completely independent as to when he shall carry out the different farm operations involving their use. Each holding, therefore, usually requires at least one pair of bullocks; consequently the number of bullocks continues to increase in the country as a whole as the average size of the area cultivated per bullock decreases. The provision of feed for an increased number of animals, therefore, increases the demand on the land for this purpose.

The following figures show how the area of cultivated land per bullock has been changing during the past twenty years or so (26 and 27).

YEAR		AREA SOWN	AREA FALLOW	TOTAL AREA	NUMBER OF BULLOCKS	AREA PER BULLOCK
		Thousands	*Acres*		*Thousands*	*Acres*
1918-19	..	215,856	81,228	297,084	46,076	6·45
1923-24	..	270,160	59,368	329,528	51,131	6·44
1928-29	..	277,131	55,728	332,859	53,860	6·18
1933-34	..	285,171	55,760	340,931	57,643	5·91
1937-38	..	281,812	58,842	340,654	56,700	6·01

Where the size of the holding is large, particularly in the case of college, government and large estate farms, and where good management practices are commonly followed, the acreage which one pair of bullocks may handle is much larger than the average for India. One pair of bullocks at the Allahabad Agricultural Institute, for example, handles about 29 crop acres or 20 acres of area, that is 10 acres per bullock (72). While this area should increase as better bullocks are used and as management practices improve, the area per bullock for India as a whole will undoubtedly continue to decrease for the reasons given.

Misra (72) showed that the cost of maintaining a pair of bullocks for one year, under the conditions he studied, was about Rs. 307-8-0. His bullocks worked 66 per cent of the time, or about 240 days a year. At this rate the cost per pair-day for bullock labour was Rs. 1-4-6. Dr. Wright (113), on the other hand, suggested that the average cost of maintaining a pair of working bullocks in India was about Rs. 175-0-0. He does not indicate what proportion of the time the animals actually work. Unfortunately, no one seems to state clearly the average number of days bullocks are worked during a year in this country. It is questionable whether they work as much as those studied by Misra. The cost of maintaining bullocks will remain almost the same however much the animals work; the cost per day of work will increase as the number of working days decreases and decrease as the proportion of their time spent at work increases. The average pair of bullocks on an Indian farm does not work over 150 days a year at the most, probably many fewer. If it costs Rs. 175-0-0 to maintain a pair of bullocks for a year during which time they work 136 days, the cost per pair-day will be the same as shown by Misra.

The length of the working life, the age at which it begins and the mortality rate among young calves of pre-working age will determine the number of young stock which must be raised to replace our bullocks. The investment in materials and services necessary to raise a bullock to working age, like those required to raise a female to the age at which milk production begins, must be paid for by the production of the animal during its life-time. Early maturity and a low mortality rate among pre-working age calves are essential to the economic production of bullocks. Furthermore, the greater the working life and the greater the proportion of that life spent at work, the lower the investment cost of the bullocks for each day of work they do. A bullock which does not begin work until it is five years of age and which lives for five more years during which it works only 150 days a year will work just one-half as many days as one which begins work at three years of age and lives for seven more during which it works 215 days a year, or one-third as many as one which starts to work at three years of age and lives for nine more during which it works an average of 250 days a year. The replacement cost per bullock-day of work will be even more in favour of the last two bullocks in that they will be maintained only three years instead of five before they start to work, apart from working two or three times as much. Bullocks which are produced in three years, which with good feed and care is possible, will have cost more when they begin to work than those produced in five years will cost at the end of their third year; the latter, however, will have cost considerably more than the former at the time they begin to work. Replacement cost also will increase as the mortality rate of pre-working age calves increases. If the mortality rate is 75 per cent, as it may be under certain conditions in our village areas, four calves will have to be kept in order to have one left at working age; at 25 per cent mortality, four new-born calves will give three at working age.

If cows which are now maintained for producing working bullocks were to give more milk, produce more calves or be worked they would be more economical, thereby reducing the contribution they make to the cost of our bullocks. A cow which is maintained ten years to produce two male calves, which may later become bullocks, if they do not die as calves, produces more expensive bullocks than a cow which produces four such calves during the same time. If either cow were to produce sufficient

milk that not only could the needs of the calf be met, but a surplus remain, to be either consumed by the family of the owner or marketed, she would produce still cheaper bullocks. Finally, if such cows were to be worked more than they now are it would result in much more economy in the production of bullocks and/or the cost per bullock-day or cattle labour. Nearly 3,000,000 cows are now used only for work in India (27). There is no reason to believe that those used for breeding cannot also be worked to some extent. They might prove useful for meeting the demand for bullock power on the farm during the planting and harvest seasons without interfering appreciably, if at all, with their production of calves or milk. This should be one means of meeting the shortage of cattle labour at such seasons and should be particularly feasible in the case of cows which do not produce calves more often than every 20 months or so. Such a practice would require better feeding of and care for our cattle. New implements might be designed especially for the buffalo as another means of increasing the total output of animal labour in this country.

Milk

Recent estimates of the total production of milk in India vary from 20,000,000 to 39,000,000 tons a year. The most recent, however, is 7,447 lakh maunds (18). To this may be added 2·5 lakh maunds of milk equivalent which represents the excess of imports over exports. This gives a total of about 27,300,000 tons. Of this, 1,154 lakh maunds are fed to calves, 1,133 lakh maunds are retained by the producer for himself and his family and 5,162·5 lakh maunds are marketed. A total of 6,295·5 lakh maunds, therefore, are used for human consumption, giving an average of 5·8 ounces of milk or milk equivalent in the form of milk products for each person in India a day. This is less than one-third enough, however, to provide everyone with that amount which authorities say is required to meet those nutritional needs which milk is best suited to meet.

Since a much smaller portion of all milk is consumed by those who produce it, that is largely rural people, than is consumed by those living in urban areas, the greatest potential market for milk is in the rural areas. It is essential, therefore, that our milk

production be increased as rapidly as possible to meet not only the need in our cities, but the far greater need in our 700,000 villages.

When all items are considered, a cow must produce at least 2,000 to 2,500 pounds of milk in a lactation before she becomes profitable. The yield required of a village buffalo cow under different sets of conditions of cost is between 2,100 and 3,300 pounds in a lactation before a profit of between 10 and 25 per cent will be realized, if the milk is used for ghee making (110). The average production of milk by either the zebu or the buffalo is considerably below these figures, consequently it is safe to presume that a majority of our cows are unprofitable as producers of milk or butter fat. There is a service they perform, however, the value of which economists have yet to assess satisfactorily. Warner and Joshi discuss this service by the following statement (110):

> "Many American farmers maintain one or more cows primarily to provide small amounts of cash regularly by the sale of cream. From a purely economic point of view these cows are frequently maintained at a loss. The availability of some currency at regular intervals for incidental and sometimes very necessary purchases, however, has a value which cannot be accurately assessed. It is likely that the cost of such money is higher than if it were borrowed at current interest rates, but it is not always possible to borrow the necessary money. More important yet, perhaps, is the fact that many farmers prefer this higher priced money to borrowing it at interest. Such practices are usually most frequent where money is most scarce. It may be, therefore, that this is a more important factor in our villages than on the American farm. Economists, we believe, have yet to assess the value of such a service which the farmer can supply *apne ap se*."

Because ghee can always be traded for currency, even in the most remote village, and because interest rates are frequently ridiculously high, particularly for small sums of money, the service the cow renders in providing quantities of ghee and thereby making currency available to the village farmer is almost inestimable.

Reports of the cost of producing milk on organized farms varied from 6·49 pies a pound for half-bred cows (51) to 15·82 pies for Murrah buffalo cows (49) during the past decade. The cost of production of one pound of butter fat under the same conditions varied from Rs. 0-13-3·1 (51) to Rs. 1-3-0·7 (49) during the same period. The retail price of milk sold by such farms has varied from 14 to 10 pounds to a rupee, or from 13·7

to 19·2 pies a pound. Both Kartha and Joshi *et al* showed that the zebu produced milk cheaper than the buffalo, that the buffalo produced butter fat cheaper than the zebu and that the half-bred cow produced both milk cheaper than the zebu and butter fat cheaper than the buffalo. The utility of the zebu-taurus cross-bred cow (crosses of the zebu with the western cow or *Bos taurus*) for milk production under village conditions is yet to be determined. Opinions differ considerably as to their utility under farm conditions.

The zebu is maintained primarily for draught purposes, the buffalo for producing milk. The fact that there are nearly 3½ mature female buffaloes to one mature male buffalo indicates the comparative importance of the former. Kartha (51) says, "Under the existing conditions the buffalo is more economical for the villager than the cow (zebu) as the free grazing she gets on the roadside enables her to beat the cow in the production of both milk and butter." The production by the buffalo of larger quantities of milk containing a higher percentage of butter fat, as compared to the zebu, makes the buffalo the more economical of the two under village conditions. The principal market for the producer of milk in the more remote areas is for ghee; in these areas it is more profitable to keep the buffalo. It is estimated that 57 per cent of our milk is converted into ghee and that, although we have nearly 2½ zebu cows to one buffalo cow, the buffalo cow produces practically one-half of our milk. The buffalo is and will remain an important dairy animal for India.

The value of our milk alone about 1937 was roughly equal to all rice produced in India and three to four times the value of all wheat (113). The tremendous price changes which have occurred during the past five years or so, however, have changed not only the total value of each agricultural product but their comparative values as well. Whereas Wright indicated that the value of all milk was about Rs. 300 crores, the same amount of milk at the present, retailing at 5 pounds instead of 12 pounds to a rupee, is about Rs. 720 crores. He showed that 33 million tons of rice, the estimated production prior to 1937, was valued at about Rs. 100 a ton at that time. On the other hand, in 1937-38 the total production of rice in India was about 31 million tons (26). At two seers to a rupee, a common price in cities of northern India at the present time, this rice would be worth

about Rs. 540 a ton or a total of nearly Rs. 1,664 crores. At the present price of about Rs. 15 a maund, the production of wheat in 1937-38, that is about 11,797,000 tons, would be worth about Rs. 478 crores.

Manure

Olver and Vaidyanathan (77) made a very rough estimate of the annual value of the manure produced by our cattle. Their figure, quoted by Wright and used here, is Rs. 270 crores. It is based on 1929 prices, using Lander's estimated production of four tons of dung and one and one-half tons of urine annually by a mature bullock, as well as on the assumption that one-half of all dung and urine is wasted or burned. No information seems to be available to show the value of cattle manure as a fertilizer for different crops in different parts of India nor to show the proportion of the dung which is used for fuel, which is undoubtedly rather large. Farmyard manure is considered one of the best fertilizers for general use. It not only contributes food nutrients which are essential to plant growth but organic matter or humus which improves the physical conditions of the soil. The value of such manure will depend upon the animal by which it is produced, the type of feed the animal receives and the method of storage. About two-thirds of the farm livestock in India, except poultry, are cattle; furthermore, the amount of dung and urine produced by one bovine is as much or more than that of any other farm animal. Consequently, cattle probably contribute nearly 75 per cent of all manure coming from farm animals. Unfortunately, however, it is cattle dung which is generally used for fuel.

The tremendous shortage of roughage feed for all classes of farm animals, particularly the bovine, probably limits the production of dung; but what is more important, however, it greatly reduces the amount of manure which is produced by making it almost impossible to mix straw, hay and other such material with the dung to increase its volume. Farm animals are rarely given such material for bedding because it is so desperately needed as fodder. Such material is not mixed with the dung and converted into manure, therefore, as is so commonly done in many other countries.

CHAPTER II

THE MANAGEMENT OF DAIRY CATTLE IN HEALTH AND DISEASE

The management of dairy cattle involves problems both of maintaining health and of increasing utility by genetic improvement through selective breeding. A cow can produce milk to the limit of her inherited capacity only if her health and the feeding and other environmental conditions make this possible. A cow may appear healthy, but because of poor feeding, lack of an adequate water supply, too little protection from the sun or from flies or improper treatment by the *gwálá* she may not produce the quantity of milk that should be expected of her. On the other hand, it is possible to overfeed an animal, thereby reducing the returns for each unit of feed expended. The cow is a biological machine. She responds not only to the supply of feeds, water and physical comforts, but also to human care and attention. She enjoys kind treatment from those caring for her. The dairy cow must at all times, however, be considered a means by which food materials in the form of fodder and grain are converted into milk. Feeds containing all the necessary nutrient materials in the proper proportions, adequate clean drinking water, protection from the elements and proper medical care must be provided at all times, however, in order that the greatest possible returns are realized. Efficient management of the dairy herd also includes careful selection of the best, *that is the most economical*, individuals from which to breed new animals to propagate the herd. This is necessary in order to improve the herd as quickly as possible. The greatest possible returns must be realized for each unit of expense.

The greater the number of days, for example, during the lifetime of a cow when she is producing milk, the more economical she is likely to be. As a heifer she may freshen at two and one-half years of age. If she fails to freshen before her fourth year she thereby loses a year and a half of producing life which she will never recover. Whenever breeding or other difficulties cause an extended dry period, there is likewise a loss of producing life. More milk may be produced during an extended lac-

tation than during a normal one, but the utility of the animal is usually less since this results either in a shortened dry period, which does not permit full physical recovery from one lactation before another begins, or in a longer calving interval. Health permitting, cows should be bred again within 100 days after parturition. The criterion of utility in any animal is the lifetime production of milk, calves, body growth, services and/or work, in relation to the amount of food and services consumed. An animal which first calves at four years of age following with calving intervals of 20 months will have completed four lactations and produced her fifth calf at ten years, eight months of age. On the other hand, an animal which first calves at 2½ years of age following with calving intervals of 14 months will have completed seven lactations and given birth to her eighth calf at ten years, eight months of age. The lifetime production of the latter animal, both of calves and milk, will definitely be greater than the former. She may consume more feed, but not proportionately more. Additional discussion of this point will be found in Chapter XII. A young animal which shows 3·8 pounds gain in body weight for each 100 pounds of grain and fodder consumed is obviously more economical than one of similar parentage of the same breed which gains only 3·5 pounds in body weight with the same feed.

The physiology of reproduction and the theory of inheritance are too complex to be discussed in any detail here. Characteristics are transmitted from parents to offspring through genes. These are found in every body cell and transmitted in the gametes or germ cells which are the egg cell of the female and the sperm cell of the male. Reproduction results from the union of an egg and a sperm. In higher animals this occurs shortly after coitus. It is known as conception. The new individual, called the foetus between conception and birth, develops in the uterus of the female. The foetal life or gestation period is 283 days for the zebu and 304 days for the buffalo.

Genes occur in pairs in the body or somatic cells. By a process of reduction division in the formation of gametes or sex cells, known as gametogenesis, only one gene of each pair passes into the egg cell or into the sperm cell. The union of an egg cell and of a sperm cell in the formation of the first cell, known as the zygote, of a new individual results again in the pairing of genes. The mechanics by which characters from the sire of male parent

and from the dam or female parent combine in the offspring is therefore obvious.

Genes may be dominant or recessive. Where two of one kind constitute a pair the condition is called homozygous; where the pair consists of one of each kind the condition is called heterozygous. The physical character of an animal will be that of the dominant gene if both or even one of the pair of genes involved is a dominant gene; it will be that of the recessive gene only if both of the pair of genes involved are recessive. The dominant gene masks or overrules the effect of the recessive gene, but does not eliminate it. If the condition is heterozygous the animal will be a carrier of the recessive gene, that is it will produce two kinds of gametes, one containing the dominant and one the recessive gene. Gametes produced by the homozygous individual will be of one kind only. They will always contain the dominant gene if the parent cell is homozygous for the dominant gene, or the recessive gene if the parent cell is homozygous for the recessive gene.

Characters that are inherited in a simple manner are the result of the action of only one pair of genes. The inheritance of certain characteristics, however, may involve several pairs of genes. The genetic explanation of the inheritance of the economic characters of dairy cattle, that is milk producing capacity and butter fat percentage, has not yet been determined. If, however, the dairy cow is to be employed effectively in the conversion of food energy in the form of fodder or concentrates into food energy in the form of milk, and if, as is now thought to be true, the quantity and the quality of milk are independently inherited characteristics, the utility of a milking animal can best be expressed in terms of the product of the amount of milk and its butter fat content in relation to the feed consumed.

The quality of any product of human effort depends upon the quality of the original or raw materials used in its formation and the skill with which such materials are combined and/or processed. In producing high quality dairy cattle the raw material is essentially the germ plasm of the breeding animals; the combination of this material constitutes the breeding programme and the general herd management practices. In the selection of raw material for this purpose, the quality of the germ plasm itself cannot be satisfactorily observed or conveniently measured. One must depend upon the general appearance of

the animal and its record of production, if any. (The selection of individual females should be based upon their physical appearance, general health and production of milk and butter fat. While considering breed type and general physical characteristics, only those cows which have produced the most milk and the most fat or which have produced milk and/or fat the most economically should be used for breeding purposes.) The case of bulls is different in that they have no production records upon which to base their selection. In their case the breeder must, in the first instance, rely upon the production records of the dam, full sisters, if available, or half sisters. As daughters of a bull come into production their records can be used as a more reliable index of the producing potentiality of the bull. The performance of daughters, however, must always be considered in comparison with that of their dams to assure reliability. Furthermore, the general feeding and management conditions of both female generations concerned must be taken into account in making dam-daughter comparisons, whether to determine the producing potentiality of the bull or merely to compare the two animals as producers of milk. The selection of the germ plasm particularly that of the male, is obviously not a simple matter.

A simple means of determining the producing potentiality of a bull is indicated by the formula: $S=2H-D$, in which S is the potential producing capacity of the bull or sire; H, the production of the dughter or heifer; and D, the production of the dam. This formula provides a simple intermediate index for the bull.

The best method or methods of housing dairy cattle of different ages in India has not yet been determined. A considerable amount of information is available in this respect in certain other countries. What methods may be best there, however, may not be altogether applicable in this country. In the great dairy areas of the world, particularly in north-central and north-eastern United States, in England and in Denmark, the climate differs so greatly from that of most of India that it is not reasonable to advise the use of various types of cattle sheds or barns for use here which have proved satisfactory there.

Considerable protection can be provided in India, particularly against the hot sun during April, May and June, by ordinary shade trees. Protection from the sun as well as from the rain would be provided by a shed open on all sides. The

simplest shed of this type, although not necessarily the most economical over a period of years, would consist of a roof of grass thatch supported on wooden poles. Such a shed costs very little to construct. It protects the animal from the sun and sheds the rain sufficiently to provide a dry area during rainy or monsoon weather, except where rain is accompanied by strong winds. Such a shed must be frequently repaired, however, so that although involving a comparatively low initial cost, it soon becomes an expensive type of structure as a result of frequent repair and replacement.

A more pucka shed, built with steel poles which support an iron sheet, asbestos sheet or tile roof, is comparatively costly to construct but much more durable, consequently it is possibly as economical a structure ultimately as the simpler grass roofed shed. If desired, a grass thatch may be placed on top of the roof of the more permanent shed to make it more comfortable for the animals during the very hot season.

A shed which offers the advantages of that just described, but with the additional advantage of protecting the animals from winds, especially those during the cold winter nights, is enclosed on three sides. The better sheds have hard floors of bricks and/or cement.

Exercise is essential for the proper growth and development of the young dairy animal as well as for the health of those of all ages. It is not advisable, from this point of view, to keep the animals tied at all times. They must be allowed a certain amount of freedom which can best be provided by the use of paddocks or corrals. These are small areas, enclosed by a fence which is of such construction as to dissuade or prevent animals from going through it. Paddocks should always be well drained and should be provided with shade trees even where sheds are used. Paddocks should be located, so far as possible, on soil which is highly absorbent as well as on ground that is sloping to facilitate drainage. The heavy rains which occur in most of India during the monsoon make it imperative that rain water be removed rapidly by surface flow and/or absorption. Unless drainage is rapid, water soon accumulates producing undesirable mud holes in which animals, particularly the buffaloes, may wallow and which may be a source of disease contamination. Highly absorbent soils facilitate drainage and should be selected for the paddock site if possible.

Dairy animals, except possibly pregnant animals at parturition and milking animals, may be fed both roughage and concentrate feeds in the paddock. It is unnecessary to provide specially constructed feed boxes or feed stalls in the sheds for this purpose. Very satisfactory racks can be made, either permanently fixed in one place or movable, in which to feed both fodder and concentrate feeds. A feed rack usually consists of a large trough measuring about three feet wide by one foot deep, the length depending upon the number of animals to be fed at one time. It may be constructed of wood or of other materials. It should be equipped with a guard rail fixed slightly above the edge of a trough. The distance between the upper edge of the trough and the guard rail should depend, firstly, on the age or the size of the animals and, secondly, upon whether they have been dehorned or not. The distance should be such that the animal must lower its head slightly in entering it into the rack for feeding purposes. Such a height will cause no discomfort to the animals during feeding as it will come immediately above the neck when the head is held in the normal position. It would be necessary, however, that the animal lower its head slightly in order to remove it from the feed rack. Such a height would make it inconvenient for the animal to fill its mouth with feed and then, by swinging its head about, throw considerable quantities to the ground. It will also dissuade them from fighting with each other while feeding. The permanent feed rack should be surrounded by a sloping hard brick, cement or *kánkaṛ* floor at least six feet wide.

For young calves at the age at which grass is first supplied, a feed rack of a slotted construction is probably better than that just described. The advantage it offers for feeding calves, as compared to the trough type of feeder, is that the grass is readily available and in sight of the calves.

An ample supply of fresh clean water for drinking purposes is necessary for dairy animals of all ages. During the earlier weeks of calfhood, water is usually provided in only small quantities and may be provided in the feed pail as milk is provided. As the animal gets a little older, however, it will need water more frequently and in larger quantities. To meet this need, water should be available at all times in the paddock. Tanks into which water is placed from time to time or which are equipped with automatic valves in the supplying tap lines may be

used. Such tanks should be regularly washed, followed by thorough drying by exposure to the sun, and disinfected by white washing. Cleaning should be done daily to prevent the accumulation of various kinds of fungi or other infective organisms.

Milk contains about 85 per cent water. While the calf is receiving milk little water will be required other than that which is contained in the milk, although after the calf is a few days old water should be offered at frequent intervals. When milk is discontinued it is absolutely necessary that all the water the animal will drink be accessible at all times. Too frequently it is forgotten that the calf has, while milk is fed, had large quantities of water, although very little water was provided as such. It is wrongly assumed to the detriment of the thriftiness of the calf, that since very little water was supplied, little need be now, even though milk feeding has been discontinued. Water must be supplied in adequate quantities to animals of all ages. The quantity required will vary with the season, with the feed received, with the age and health of the animal and upon whether it is milking or dry. For mature animals the amount of water, including that contained in the feed, required is approximately four pounds for each pound of dry matter in the feed, although high fibre and high protein feeds will make more water necessary. An additional four to five pounds of water for each pound of milk being produced are also required. In the absence of sufficient water the health and/or production can be expected to be far below normal.

Where convenient, natural or cultivated grazing areas should be used in feeding the cattle. This, however, is not always possible but is advisable where facilities permit.

All animals need salt. The grain ration used for feeding the different groups of daily animals should include a small proportion of salt. In addition to this it is considered advisable to provide salt licks in the paddocks or sheds. Ordinary rock salt should be placed in the feed racks where it will be accessible at all times or it may be made available in the shed by putting it in a small box.

All sheds or barns should be so constructed as to assure proper ventilation. The animal should be provided at all times with fresh clean air to assure sound health. The necessary fresh air can be provided if the animal is kept tied at all times in the

shade of trees, while it cannot be provided if the animal is housed in a manner commonly used under village conditions, that is in a small, dark, poorly ventilated room that is a part of the family residence of the owner.

Milking barns should be of permanent construction, should be well ventilated, well lighted and should have floors that are well drained. The construction of different types of structures, including the milking barns, is discussed in Chapter VII.

The lifetime of the dairy animal may be divided into several stages, such as the calf, the growing animal, the pregnant animal, the milking animal and the dry animal. The feed and other requirements of these different stages vary somewhat so that it is well to discuss them separately. A brief discussion of the management of the dairy animal in health and disease during each of these stages follows.

The Calf

At birth a membrane, known as the amnion, may cover the mouth and nose of the calf; mucus as well as the somewhat viscous amniotic fluid may fill the nasal passages. Assistance by an attendant is frequently necessary to clear these obstructions to enable the calf to breathe properly. Artificial respiration may be helpful if the calf is born weak or if breathing does not begin normally otherwise. This should be followed by proper treatment of the navel or umbilical cord. Such treatment consists of cutting off the cord with sterile scissors about one to one and one-half inches below the abdomen and thoroughly disinfecting it with tincture of iodine. It is sometimes suggested that the cord be tied either by making a knot in the cord itself or by applying a suture or string. It seems better not to do this as it interferes with drainage during the decomposition and drying of the cord tissue. The calf may then be wiped off and dried with a coarse cloth, such as ordinary burlap, which has been thoroughly cleaned beforehand.

The calf may ordinarily be allowed to get to its feet when inclined to do so. Usually two or three hours may elapse before it will feed for the first time, although as much as twelve hours may elapse before forced feeding should be used, whether the calf is to be weaned or not.

Three methods are used for feeding calves during the early part of their life when milk is necessary. These are: natural nursing, artificial nursing, and pail feeding. Calves are said to be unweaned if fed by the first method or weaned if fed by either of the other two. It is imperative, whatever the method followed in feeding the calf, that it receive the colostrum produced by its mother during the first few days. Thereafter herd milk will be satisfactory. Where a large herd is maintained and the calves are weaned, it is helpful for calf feeding to use milk from those cows that have most recently freshened. Frequent small amounts of milk must be given to young calves. The milk should always be given at body temperature. For unweaned calves the udder of the cow should be washed off well before allowing the calf to suck, to avoid contamination of the calf from the dirt on the udder. For weaned calves the feeding pails must be scrupulously clean bacteriologically. Feeding must be at regular intervals.

Weaning involves teaching the calf to feed otherwise than from the udder of its mother or of another cow. This method of feeding is advised, although not always feasible. The calf should be weaned at birth or before it is more than three or four days of age. Individual cows react differently to the removal of their calf. If all calves are removed immediately after birth, particularly from heifers, there will be very little if any difficulty experienced. In the more highly developed dairy countries of the world it is found that little difficulty results from removing the calf from the cow on the third or fourth day. It seems, therefore, that the common belief in India that the cow must not see her calf, and to prevent this her eyes must be covered, is invalid. There is reason to presume, on the other hand, that the reaction of our cows to the removal of the calf is more severe than that of cows in certain other countries. The practice of natural nursing is used very widely in India. Our cows seem to have been conditioned to *expect*, more probably to *demand*, the calf, although when properly handled they will get along very well without it. It is commonly observed that if a cow has never had her calf with her she will produce a normal flow of milk without it. If, on the other hand, the calf is allowed with the cow throughout a lactation, possibly only part of a lactation, she can be expected to demand it thereafter.

Natural Nursing

In the natural nursing method the calf is allowed to suck the teat of the cow, usually its mother, to obtain the milk. A common practice is to allow the calf with the cow only at milking time, thereby stimulating the flow of milk and making it possible to withdraw some by hand. At this time the calf is generally allowed to feed either before and after hand milking or only afterwards. In some cases the calf may be allowed access to two quarters of the udder, the milk being removed by hand from the other two. Whenever no milk is to be withdrawn for use otherwise, the calf may be allowed to remain with the cow at all times. This is not usually permitted, however, where milk is to be obtained for use in the family or for sale.

Of these different procedures, the latter is probably to be preferred, since the calf is thereby able to get a little milk at any time it wishes. Although the cow may not produce enough milk for adequate nutrition of the calf, what the calf actually gets is more likely to be sufficient if this method of feeding is followed than otherwise. Giving two quarters to the calf is probably the next best procedure to follow in feeding calves by the natural nursing method. In this case the milk obtained by the calf is a composite of that produced by the cow, that is, it contains the normal proportions of fore milk, middle milk and strippings. The amount of milk the calf gets by this method can be roughly estimated by noting the amount obtained from the two quarters that are hand milked. Allowing the calf to nurse both before and after hand milking is a better procedure than allowing it to nurse afterwards only. It is stated elsewhere that the fat content of the strippings is considerably higher than that of the fore milk or of the middle milk. Excessive fat in the milk consumed by the calf, which would likely result from the calf nursing the cow only after hand milking, may cause digestive upsets. Furthermore, such a procedure would probably result more frequently in the calf getting too little milk than would be true with any other procedure. Not only would the fore milk tend to dilute the fat content of the strippings, if nursing were permitted both before and after hand milking, but it probably would add to the volume of milk the calf actually received.

Every *gwálá* tends to assess his need for, that is the value of, the calf. Its value may depend upon its need for stimulating the milk flow in the cow, upon it becoming a milk producing

cow or a bullock or on a less rational basis. Its importance to the *gwálá* will determine how much milk he will allow it to have. If allowed with the cow at all times or if allowed two quarters of the udder, the amount of milk the calf will receive will be determined by the production of its mother. On the other hand, if allowed to nurse before and after or only after hand milking the amount of milk it will receive will be determined by the rate of milk flow on the part of the cow and by the time allowed by the *gwálá*. The *gwálá* will allow the calf to nurse for a length of time which he will arbitrarily determine at each milking. The quantity of milk obtained by the calf will vary widely, therefore, for the value of the calf will vary from day to day, depending upon the milk flow, the need for the milk on the part of the *gwálá*, his temperament and possibly other factors. In certain countries the practice of using a nurse cow is sometimes followed. This involves the use of a cow with which two or more calves, depending upon her production, are placed for raising by the natural nursing method. They are usually allowed with her at all times.

Artificial Nursing

The artificial nursing method involves the use of a rubber teat or nipple. There are different types of such nipples available outside of India. One is fixed in a horizontal position and is supplied with milk either through a metal tube fixed into the side of a pail or trough containing the milk or through a rubber tube through which the milk flows by siphoning or gravity. Another type of nipple floats in the milk in an upright position, permitting the calf to grasp it in the mouth as the head is lowered into a feeding pail set on the floor. In either case the calf takes milk into its mouth by sucking the rubber nipple in the same manner that it would suck the teat of the cow.

Pail Feeding

The pail feeding method makes use of an ordinary open-top pail into which the milk is placed. The calf is taught to drink from such a pail rather than from the teat or a nipple. In teaching the calf to drink in this manner one should place the fingers of one hand either across the calf's nose or into its mouth, preferably the former. In either case the calf should only be allowed to nibble at the fingers while they are slowly moved downward into the milk; the calf will follow them readily. As

the nose enters the milk the calf will taste it. The fingers should be removed at once, never allowing the calf to suck them while in the milk. It should be taught that the milk is found in the pail, not on the fingers. This need be repeated only a few times before the calf will learn that the head must be put downward instead of upward, as in the natural position, and that on sucking at the milk it will enter the mouth and can then be swallowed. Large quantities of air may be swallowed if the calf drinks milk from a pail. The calf should be permitted to swallow as little air as possible, however, for excessive quantities may cause some digestive difficulties.

General Management of the Calf

The nutrient requirements for proper growth and development in the young calf are given by several authors (73, 30 and 114). A feeding schedule that will supply these requirements is given in Appendix I. This schedule is the same for male and female calves, either the zebus or buffaloes.

It will be noticed that, so far as the milk to be supplied is concerned, whole milk alone is supplied during the first two weeks. Skim milk is substituted gradually for the whole milk until from the ninth week skim milk only is continued to the sixth month. It is estimated that the average calf in this country gets not more than 300 pounds of whole milk during its first five months; no skim milk is provided (18). In another section of this text the food values, in Calories, of whole milk and skim milk are given. Using these figures we find that, according to the feeding schedule referred to here, a calf should be provided with from 4¼ to 7½ pounds of whole milk daily for the first 55 days or so, supplying nearly 115,000 Calories, plus from 3 to 15 pounds of skim milk daily from the fourth week through the sixth month, supplying nearly 244,000 Calories. This is a total of about 359,000 Calories. On the other hand, the average calf in India gets about two pounds of whole milk daily for the first five months, supplying about 103,000 Calories ! These figures are exclusive in each case of the food energy supplied in the form of grain and roughage.

This feeding schedule, based partly on experience at the Agricultural Institute, Allahabad, is not a rigid schedule, but may be modified for calves that are stronger than usual by stopping the whole milk a little sooner, perhaps at the end of the

fourth week, and substituting skim milk. Or it may be modified for very weak calves by continuing the whole milk at 2½ pounds in the 5th, 6th and 7th weeks, with no skim milk being given until the 7th week when one pound is to be given at each feeding (see figures included in the schedule in brackets). Thereafter the schedule is followed as given.

Small quantities of concentrate feed or grain mixture are fed from the second week, when grass is also given. The amounts of these feeds increase steadily to the seventh month when skim milk is discontinued and the calf goes on dry feed altogether. Silage is not given before the 10th week.

The calf should be kept in clean and well drained surroundings. The calf shed should offer protection from rain and sun, it should be cool and well ventilated, yet drafts, particularly during the monsoon and the winter nights, should not be tolerated. The calf should have a paddock in which to exercise whenever desired. Protection from crows, dogs and other animals should be provided. Fine, nutritious grass should be made available at all times after two weeks of age. This may be placed in an open rack, preferably inside the shed. The calves should be tied separately at feeding time for which purpose small stanchions may be used. Immediately after feeding, calves will suck each other, either on the nose, ear, navel, scrotum or dewlap. During the first week, before grain is fed, the nose and mouth should be well washed, just after the milk is fed, with clean warm water to remove any milk that adheres to these parts and encourages sucking. When grain is fed it should be given immediately after the milk, while the calf remains tied. This removes any taste of milk from the mouth and discourages sucking. The man handling the calf should be gentle at all times as the habits formed at this age may influence the temperament of the animal later in life. Regularly grooming, especially by use of a brush, keeps the coat of the calf in good condition and teaches the calf to respect its caretaker.

For the first few weeks of age the rudimentary horn of the zebu calf is a loose, button-like structure embedded in the skin covering the horn site. If dehorning is considered desirable, it is best to do so at this time, or at about ten days of age. The hair is clipped off very short immediately over and around the horn button. Vaseline, or other salve, is applied about but not on the horn button. The horn button is then rubbed with

a slightly moistened stick of caustic potash, that is potassium hydroxide (KOH), until a slight pink appearance is noted. The entire button must be so treated, care being taken that none of the surrounding skin is included. The salve surrounding the treated area, if properly applied, will prevent the moisture, which appears at the horn site as a result of the application of the caustic potash, from running across the head and face. Should this happen, serious skin burns will result. The person applying the treatment must protect his fingers from the caustic potash by keeping that part of it dry with which it is grasped and by wrapping it with several thicknesses of paper.

The calf should be permanently marked, shortly after birth, for identification purposes. This may be done by branding, by fixing metal tags, containing numbers, into the ears, by systematically notching the ears or by tatooing. Brands are applied by use of hot irons shaped according to the marking desired. Branding is usually done on the thigh or shoulder, although it may be on the hoof or horn. The latter brands are much smaller and generally less permanent, however, than the former. Those on the body may be several inches high so they can be seen from a distance. Branding is not a desirable means of marking animals because of the method by which it must be done and the damage it may cause to the hides, although brands, especially those on the body of the zebu are quite permanent. Brands of two or three figures not more than three inches high placed as low as possible on the thigh or shoulder will cause a minimum of damage to the hide for use as leather. The many large and irregular brands, which are sometimes scattered over the body actually make the hide of little if any use for tanning purposes and serve no purpose whatever in identifying the animal which could not be served by smaller, more carefully planned brands located where the least possible damage to the hide would result. It will be noticed, however, that brands on the body of the buffalo tend to fade out within a few years.

Numbered metal tags may be fixed in the ear at very little expense. This application causes very little discomfort to the animal if the ear and the tags are sterilized just before insertion to prevent infections which may sometimes occur. Such tags cannot be read at a distance and are rather easily torn from the ear and lost. Notches in the ear margins and small punctures in the ear body provide permanent identification and can be

made with far less discomfort to the animal than branding on the body. Such marks can usually be identified at a greater distance than the numbers on ear tags. Like branding, however, this method of marking disfigures the animal somewhat. Tatooing combines permanency with ease of application. The identification mark, generally a number, is commonly fixed on the light coloured skin in the inside of the ear. So far only black tatoo ink on light coloured skin is used in India. Tatoo marks cannot be read at a distance; they are, however, permanent and can be applied with perhaps the least discomfort to the animal. So far as this method of marking can be used it is to be preferred.

The Young Animal

Growth normally begins in a young dairy animal shortly after birth. It continues until at least four, possibly six or seven years of age, depending upon the kind and amount of food available during this period. The rate of growth varies with individuals, but is affected by the quality and quantity of feed available, the age and health of the animal and other factors. The maximum rate of growth for Red Sindhi heifers on good feed occurs between 10 and 23 months of age (109). The time at which dry feed, or feed other than milk, should begin and the amounts that are to be given for best results have already been indicated. After milk is discontinued the animal must depend entirely, upon dry feeds for its nourishment.

Careful attention is necessary during the growing period to assure proper growth and development. The nutrient requirements for this purpose must be supplied through a variety of feeds, namely, fodders and grains.

Two types of maturity, sexual or physiological and physical, occur. Under proper conditions of growth and development, sexual maturity will occur perhaps several months before physical maturity. On the other hand, they may occur, as they do in the case of most of our village animals, almost simultaneously. This is due to improper development resulting from poor feed and care during the growing period. Some workers in the West, for example, say that the milk production in a cow's first lactation may be considered approximately equivalent to seventy per cent of mature production; some consider the production of the

third lactation as the mature production. Because of the semi-starved condition of so many of our cattle, both sexual and physical development are retarded. This results in many of our cows giving their highest yield in the first, some in the second, lactation.

A good breeding practice is to breed all zebu or crossbred heifers on the basis of body weight rather than age. For Red Sindhi heifers this weight might be between 400 and 500 pounds. The weight chosen for this purpose should be that which is reached at the end of the period of maximum rate of growth. In the case of the buffalo heifer, on the other hand, the mature body weight and the period of growth are much greater than either the zebu or crossbred heifer. From an economic point of view, therefore, it may be worthwhile to breed the buffalo heifer at the first signs of oestrus.

Should proper growth be retarded appreciably or prevented by inadequate or improper feeding during the growing period, the young animal may become stunted. When this condition occurs it must be overcome if possible before the productive life begins; this may be milk production in the case of a heifer or service production in the case of the young bull. Otherwise it may be very difficult if not impossible to bring about recovery.

A feeding schedule that is designed to meet the needs of growing animals is given in Appendix II. This schedule is taken largely from Morrison (73). It is not possible to include in this book the necessary analytical data about feeds that are commonly available in this country in order to make the table fully useful. This information can be obtained from the manual on the Feeding of Farm Animals by Dr. P. E. Lander, from Animal Nutrition by Dr. K. C. Sen or elsewhere (73 and 85). This schedule shows the requirements of food materials on the basis of body weight. The schedule for calves, it is understood, is to be followed until the age of six months, thereafter this one for the growing animal is to be followed, the rate of feeding starting according to this schedule on the basis of body weight at six months.

For those requiring simpler suggestions about the feeding of dairy animals, including the growing animal, Appendices V and VI are included to show the approximate feeding value of different feeds as well as formulae for grain rations which will supplement different classes of roughages.

All young stock should be inoculated for rinderpest between 6 and 18 months of age. Such inoculation, if carried out properly, practically assures immunity to rinderpest, which is probably the worst contagious cattle disease we have in India.

If bull calves are to be used for bullock rather than breeding purposes they should be castrated. Castration should be carried out while the young bull is between 8 and 18 months of age. Early castration causes the animal to develop into a long boned or rangy type of bullock, while late castration results in a heavier boned, short and thick-set bullock. If castration is delayed until 3 to 4 years of age the animal may have become too aggressive to make a good work bullock in which docility is desirable. On the other hand, early castration of loose-skinned breeds prevents overdevelopment of the dewlap and sheath and late castration of the tight-skinned breeds permits the development of weight and character.

There are two methods by which castration may be performed. One involves surgical removal of the testicles. This method is not widely used in India because of the general objection to a method which results in the loss of blood. It is a successful procedure, however, if carried out properly. The other method, known as the bloodless method, is more widely used. In this method instead of removing the testicles, the small tube, known as the vas deferens, leading from each testicle upwards into the abdominal cavity, is severed by the application of pressure. The necessary pressure is applied in such a manner, by the use of specially designed forceps, that the vas deferens is severed, but the skin overlying it is not. At the same time the blood supply to the testicle is also cut off. The testicle therefore dies and is absorbed by the body as it disintegrates. The Burdizzo Forceps are those commonly used for the purpose.

The Pregnant Animal

If an animal is bred according to her body weight, physical maturity will have been approached, provided the proper body weight has been used, sufficiently that there will ordinarily be no ill effects from calving. Under village conditions of feeding and management, sexual maturity is so delayed that little danger of breeding at an early age exists. Under conditions of good management, such as on specialized dairy farms, breeding too

early may be possible. Body weight is therefore a safe criterion in such cases for age at first breeding.

The feeding schedule given for the growing animal will suffice for the heifer during pregnancy if supplemented during the last month prior to parturition. The supplement might consist of one or two pounds of the grain mixture given to the milking herd, except for the last three or four days where some other slightly laxative food may be given. During subsequent pregnancies the maintenance ration given in Appendix III will supply the requirements, except for the supplement during the last month before parturition. Simpler feeding suggestions, however, are found in Appendices V and VI.

The practice of daily brushing and grooming should be applied to the pregnant animal. Even more frequent grooming, than usual may be worthwhile as parturition approaches. It must be remembered that the dairy heifer will eventually become a member of the milking herd, when she will be regularly milked and handled in a way that is more systematic and thorough than is usually routine for her otherwise. Anything which may be done before that time to make the animal gentle, quiet and easily handled is always worthwhile. One of the best ways of accomplishing this is by regular handling and brushing. An additional practice advisable as parturition approaches is to place the animal in the milking barn regularly and, except for milking her, to handle her in much the manner of a milking cow.

The Heifer or Cow at Parturition

If the heifer or cow has been properly cared for immediately prior to calving, little difficulty should be expected at parturition. Several days previous to the date calving is expected the cow should be placed apart from the rest of the herd, preferably in a small stall, although a separate open and shaded place may suffice. The calving premises should be thoroughly cleaned and disinfected before they are occupied. This will help to reduce infections of both the cow and her new calf. Whatever care and attention will keep the cow comfortable and quiet should be provided.

About 48 hours before calving, coarse feed should be discontinued with only finely chaffed succulent fodder and finely ground easily digestible grain feed, such as wheat barn, being

given. Whatever quantities of these materials she will readily eat should be allowed. For at least 24 hours after the calf is born such feeds should be continued. They are easily digested, are palatable and have a slight laxative effect.

At the time of calving or parturition the cow should be left entirely alone except for an attendant who may be necessary if any complications should arise. The proper position of the calf is with the fore feet first, having the knees extended and the head and neck extended forward and above them. Any other position will cause difficulties for the cow and may require straightening before birth can occur normally or by the help of the attendant. Special care immediately after parturition may be necessary in case of retained placenta, infections or milk fever. Veterinary help, therefore, should be available if needed.

As soon as the calf is born it should be cared for as has been suggested above. The cow should be permitted to remain at rest until she wishes to get up. As soon as possible the attendant must again carefully clean the stall or calving area to remove any soiled material that may have accumulated. The cow may be carefully washed off, so far as the place in which she is kept and the climate make it feasible to do so. Her udder, belly and flanks should be given special attention if the calf is allowed to nurse.

At the time of the first calving it is necessary to break the heifer to milk. It is imperative that this be done properly. Milking is a procedure that will be repeated many times; if the heifer is not properly broken to milk there may be continuous grief to the milker, or the cow may even be ruined as a milking animal. If the heifer has been gently, carefully and continuously handled, as is suggested in other connections, from birth until this time, she will respond very favourably to the manipulation of the teats and udder involved in the milking process. It may even be helpful if the teats and udder are gently massaged once or twice daily for a few minutes during the last few weeks immediately before the first calving. The breaking of a heifer to milk should be accomplished in a very gentle manner in order that she does not become unduly excited in the process. The worst possible thing to do at this time is to whip or beat the animal because she fails to co-operate. Any wrong done at this time may take months to overcome, if that is ever possible.

The Milking Animal

The length of time the calf might remain with the cow after its birth will depend upon the method to be followed in feeding it. It may be that the calf will be allowed to remain with the cow from a few days to several months, or it may be removed immediately after it is born. The udder of the cow, however, must be given special attention throughout the first few days, particularly during the first 48 hours. A rather serious condition known as milk fever or hypocalcemia may occur at this time in heavy milkers, although not usually in the case of heifers. It has been found that the removal of small quantities of milk from the udder at frequent intervals during the day helps very greatly towards preventing the occurrence of the condition. The amount to be removed will depend upon how much the cow produces. It should be sufficient to relieve the intense pressure but allow noticeable pressure to remain.

After the first few days the milking should be done regularly two or more times each day. Milking in each case should be complete, that is the cow should be milked dry. Several factors will determine the daily number of milkings. In the village where cows are kept as a source of milk for the family or for ghee making, the time available for her care may not permit more than two milkings daily. In organized dairies, on the other hand, where labour is hired so far as it is needed, it may be a good practice, from an economic point of view, to milk three or even four times daily. This is particularly so if the market for milk is good and high producing cows are maintained. The physiological factors involved in more frequent milkings are discussed in Chapter III. Milking three or more times daily is only possible if adequate feed is provided and the necessary care is given to maintain the health of the cow. Obviously, without satisfactory feeding such frequent milking would not be feasible.

Appendix IV gives the food requirements for milk production. As was suggested under the section on the young animal, reference must be made to other texts for the analysis of common feed stuffs. Appendices V and VI, however, are included to simplify the preparation of rations for and the feeding of dairy animals, particularly the milking animal. The nutrient con-

tent of feeds are shown and formulae are given for rations which will properly supplement different classes of roughages.

Special preparation of the milking cow at milking time is necessary. When feasible she should be completely washed and allowed to dry off. This should be followed by careful wiping of the teats and udder by the use of a clean, moist cloth just before milking. It is well to rinse this cloth in a disinfecting solution, such as chlorine solution just before use.

The sooner after one calving an animal may be bred the better. It is not feasible to breed an animal until she has thoroughly recovered from parturition and shows every evidence that her health is normal in all respects. Actually it will be several weeks, usually at least one month after parturition, before oestrus will recur. Service is not possible in the absence of oestrus, except in very rare cases when conception does not occur. If the feed and care which an animal has received up to the time of service is adequate, conception may ordinarily be expected within 100 days after parturition. Conception cannot ordinarily be effected, however, within 30 days. Some animals may require several services before they conceive. The fewer the services required the more efficient the animal is as a breeder and probably the more quickly after freshening will conception recur. The more quickly conception occurs the shorter the interval between calving. The shorter this interval, as is explained elsewhere, the more efficient the animal is as a milk producer. In some of the best herds of the world as many as 2½ to 3 services may be required per conception. If conception cannot occur within 30 days, because of the absence of oestrus, which recurs every 21 to 25 days in the zebu, and if an average of 2½ services are required per conception, the average number of days that will elapse between parturition and subsequent conception will be at least 80 to 85, assuming that oestrus occurs regularly and that service is given at each oestrus.

All milking animals should be given a certain amount of rest between the end of one lactation and the beginning of another. This is known as the dry period. It is generally suggested that 60 days is adequate if the animal is properly fed and cared for. Careful breeding records will show when an animal may be expected to calve. Sixty days previous to this date the milk flow should be dried off. Ordinarily this can be accomplished mere-

ly by discontinuing milking the animal as a result of which the milk secretion will cease and the secretory tissue thereby be given a rest. During this dry period, in addition to the recovery of the secretory tissue in the udder, the physical condition of the udder may be restored. At the same time the final growth and development of the foetus will occur. Such a dry period enables the animal body to be fully prepared for the job that lies ahead, that is, the next lactation.

Periodic tests should be made to determine the presence of infections of tuberculosis, Johne's disease and contagious abortion. These tests, which are reliable enough for practical purposes, should be carried out annually. Any animals which show a positive or doubtful reaction should be isolated from the remainder of the herd. They may then be maintained in isolation in the usual way, except that their milk should be pasteurized or boiled before being used for any purpose. Precautions should be taken to avoid carrying the infection from the infected herd to the free herd.

The Dry Animal

The time between the end of one lactation and the beginning of another is called the dry period; at this time no milk is produced. It is advisable to keep careful breeding records of all animals to assure the freshening date being known. The animal should be dried off about 60 days before this date, to allow for the recovery of worn secretory tissue in the mammary glands, to allow for the final development of the foetus and to enable the animal not only to maintain her body at its normal weight and condition but to use excess food energy in building up body reserves which may be drawn upon during the following lactation. Adequate feed must be provided at this time for these purposes.

The dry period always occurs at the end of the gestation period, which is the period between conception and parturition. The foetus at this time is increasing in size at a rapid rate. As the weight of the foetus and its attached tissues increases, the nutritional requirements for their support increases. In addition to the maintenance ration, therefore, a small amount of concentrate feed must be given daily to allow for the demands of

the foetus. Usually two to three pounds of the regular concentrate ration used for the milk stock will be sufficient.

Dry animals need no particular care beyond that given the pregnant animal. Special care is particularly important at the time of the first calving. The pregnant cow may be allowed to run with the milk stock unless there is a sufficient number of dry animals to make it practicable to maintain them separately.

Adequate water for drinking purposes, as in other cases, must be provided for the dry cows. The need for special grooming becomes greater as parturition approaches.

The Bull

The general management of the young bull is similar to that of the heifer. As sexual maturity approaches, occurring sometimes as early as one year of age, the two sexes must be separated to prevent disruption of any planned breeding programme there may be. At about two years of age light service, that is not more than one service a week, may be allowed the young bull. In order to facilitate handling a vigorous young breeding bull it is usually considered advisable to insert a heavy ring, commonly made of copper, in its nose. This ring should penetrate the thin septum between the two nostrils just above the muscular tissue of the nose, just as does the nose rope of the working bullock. Animals are quite easily handled by this means by use of a bull staff. This is usually a more reliable method of controlling bulls than any other simple method known.

The bull should be housed in a shed much like that used for other animals. There should be a small paddock provided in which the bull can move about and exercise. The fences in this case must be considerably stronger than those used about the paddocks for the cows and heifers, for the bull is a much stronger animal and is more inclined to break out than are the females. The feeding practices are in general the same for bulls as they are for the dry cows. The feed supplied must provide adequate nutrition for maintaining the body, with additional provision for the services required. A mature bull on full service should be supplied a maintenance ration, as indicated for dry cows, according to its body weight, plus three or four pounds daily of the regular milk stock ration (see Appendices III, V and VI). If the bull is properly fed and cared for he should be able

to provide 120 services a year or an average of $2\frac{1}{2}$ each week. Services should be as uniformly distributed over the year as possible. Between 30 and 70 cows may be served by one bull, depending upon the average number of services required per conception and the average length of the calving interval.

A bull should be regularly brushed and groomed to keep his skin and hair in good condition. The bull must be familiar with his attendants; the use of the brush is the best method known for this purpose.

Although provided with a small paddock in which to exercise, a bull on active service will not ordinarily exercise himself sufficiently unless forced to do so. The most practical method of exercising a breeding bull is by using him to haul manure or feed in connection with the general management of the dairy herd. This not only exercises the bull, but at the same time does the work for which bullocks might otherwise be required. It is possible to work the bulls in the fields, although there is usually sufficient carting work around the dairy farm to provide the necessary exercise without using bulls for field work. It is not wise to shoe a bull, for the shoes might prove a means by which considerable injury is inflicted on the cows at the time of service. Furthermore, it is unnecessary to work bulls so much that shoes are necessary. Two to four hours in the yoke per day for each bull will prove beneficial to his health and therefore to his virility.

The number of services expected from a good bull has been stated. It is not generally considered wise to allow the bull to run with the cows in order to breed them when oestrus occurs. It seems, however, that oestrus in the zebu and buffalo is frequently fainter than in western or taurus cattle. It is sometimes advisable, for this reason, to leave the bull with the cows at nights or for short periods of time off and on during the day in order that oestrus, especially when very faint and of short duration, might be detected and service given. Because of the rather faint and short oestrus the attendant cannot always detect it by the excited condition of the cow, whereas proper management of the dairy herd requires that services be given at the proper time. This is not possible unless oestrus is detected as it occurs and service is given promptly.

A breeding rack may be used. Its use offers certain advantages. There is greater likelihood of service occurring if a breeding

rack is used because the cow is then held in a fixed position allowing coitus to take place without interference. It also makes the use of old and therefore heavy bulls on small young heifers more feasible. A breeding rack is essential for holding the cow when collecting the semen specimen for use in artificial insemination.

Artificial insemination is feasible if carried out by a person who understands the technique and its limitations. One ejaculum from a bull may be divided into three or four parts, making it possible, theoretically, to impregnate three or four times the number of cows one bull might serve if the natural method were employed. Old zebu bulls have been found to have definite limitations for use as donors for this method of insemination. Their principal difficulty is their extremely docile, slow and almost disinterested approach to the act of coitus. Specimens of semen can be obtained from old bulls if the attendants are prepared to wait as much as 2 to 4 hours for them to attempt coitus. Young bulls can be trained to mount cows on sight and if carefully handled at all times will prove much faster donors than old bulls.

One precaution in the use of artificial insemination should be mentioned here, however, since it is so easily overlooked, especially by those who have just learned of certain possibilities of this technique. If it is possible to divide a specimen of semen from a good bull into four parts with each of which a cow may be inseminated, resulting in the production of a calf, it is proper to assume that the use of artificial insemination can greatly increase the utility of a *good bull* to a herd or to a community. A fact which is not always emphasized, but which is an extremely important one, however, is that a specimen of semen from a genetically poor bull can also be divided into four parts with each of which a cow may be inseminated, resulting in the production of a calf, just as is true in the case of a good bull. If, therefore, artificial insemination is of any value in dairy cattle improvement, this value lies not alone in its proper mechanical application, but also in the selection of the right quality of bulls as donors of semen for the purpose.

CHAPTER III

MILK SECRETION

The more important farm animals, such as horses, cattle, sheep, goats, and pigs, but excluding poultry, belong to a single biological class called mammalia. The name comes from the Latin word *mammilis* meaning "of the breast". The female of each species of animal, including man, which is a member of this class, possesses a specialized gland in which milk is secreted. Milk is a food used by the young of the species. Similar glands appear on the male, although they are rudimentary and non-functioning. In the more familiar species the young is suckled by means of a teat, an extended portion of the skin surrounding the mammary gland, to which the young fixes its mouth. By means of suction and muscular manipulation it is able thereby to draw milk from the gland. Much of the material in this chapter is taken from Espe (33).

Number and Location of the Mammary Glands

The mammary gland is a skin gland. It is usually found between the skin and the outer layers of the muscle tissue. The size, shape, location and number of these glands on the animal body varies considerably in different species of mammalia. There is usually an equal number of the glands attached symmetrically half to either side of the central line of the ventral surface of the body. There may be one gland on either side, such as on sheep and goats; there may be two glands on either side, such as on cows of the genus *Bos*; there may be a series or row of glands on either side, such as on the sow or the bitch; or there may be such less familiar distributions of the glands as on the kangaroo or the whale. In most cases there is a distinct teat or nipple designed in such a manner that the young of the species may easily grasp it by its mouth for sucking. Two glands may open into a single teat as in the horse. Usually, however, each gland has a separate teat. Each teat may have one opening, such as is true in the goat or the cow of the genus *Bos*, or several openings, as in the case of the bitch.

Physical Development of the Udder

The udder of a zebu or buffalo cow consists of four glands called quarters. The physical developments of the udder begins very early in the prenatal life of the individual. In the early stages there are no distinct differences between the male and the female. At this time there are two bands of cells, known as mammary lines, on the ventral surface of the embryo; on each of these two teat buds have appeared. In the female there soon appears a group of cells at the site of each teat bud. In the middle of this cell group a hollow space develops which is the beginning of the milk cistern. As the embryo develops to the twenty-five centimetre stage, at about the twentieth week, this opening or lumen branches once or twice. This branching eventually gives rise to the collecting system of the mature udder. By the time the foetus is about six months of age the udder has developed sufficiently that the right and left halves are distinct. From that time until birth little change is noticed except the proportionate growth of the tissues already present.

From the time the animal is born until sexual maturity occurs the only changes of any importance are increases in the amounts of the connecting tissue and of fat. On the appearance and periodic recurrence of oestrus the duct or collecting system within the gland develops rapidly until it is practically complete by the time the first pregnancy occurs.

The greatest glandular development takes place during the first pregnancy. During this time the duct system is completed; the termination of each tubule gives rise to a hollow globe-like alveolus which is lined with secretory cells. Accompanying tissues, namely nervous, circulatory, lymphatic and supporting, attain full development by the time parturition or calving takes place. The whole udder seems to grow and increase in size, giving the animal more the appearance of a mature milking cow than a young or immature heifer. As parturition approaches, the collecting system fills with secretory products while the circulatory and lymphatic systems greatly increase their capacity, adding to an engorged condition and appearance of the udder. During the last few days immediately prior to parturition, secretion of milk actively begins, subjecting the udder to a considerable pressure. This contributes finally to its enlarged and swollen appearance. By this time the development of the

udder is complete, although the activity of the organ varies with the stage of pregnancy or of lactation and with the age and health of the animal.

The gland tissue is a spongy mass including the structures which constitute the circulatory, lymphatic, nervous, secretory and collecting systems with supporting tissues. Ordinarily the more productive the gland the less connective and fatty tissues it contains, and vice versa. Low producers have, therefore, either large glands which are fleshy and fatty or small ones that are soft and pliable. High producers have large glands that are soft and pliable. The secretory system includes tiny globe-like bodies known as alveoli. These structures are hollow and are lined with a layer of secretory cells. Some authorities think this layer extends into the proximal end of the attached tubules.

Drainage of the alveoli takes place by means of the collecting system. Opening off each alveolus is a tubule, the outer or distal end of which opens into a tube that receives the milk from a group of alveoli. Such a group of alveoli and their tubules is called a lobule. The tubes open in turn into ductules which unite in large numbers later forming a duct. Such a group of lobules constitutes a lobe. A gland contains numerous lobes. The tubes open in turn into a large cavity in and at the base of the teat, known as the milk cistern. The milk is secreted by the secretory cells lining the alveoli. Either these cells become engorged with milk until they rupture, releasing the milk into the lumen, or the milk is exuded from or secreted by the sides of the cells which are near the lumen. If the cell walls are ruptured as suggested they are then rebuilt and the process is repeated. The milk drains through the various passages which have been named until it collects in the cistern. As secretion continues, the entire collecting system becomes filled with milk and may be under considerable pressure. By means of a sphincter muscle, surrounding the teat canal or teat orifice, the milk is usually retained within the mammary gland despite the pressure, although cows' teats may leak at times, particularly those of heavy milkers.

There are apparently no direct circulatory or other connections between the different quarters of the udder. The suspensory tissues of the udder divide it into a right half and a left half. This division is quite distinct due to the shape and function of the medial suspensory ligament. The division

which exists between the fore and rear quarters on each side is not so distinct. The general shape of the udder is symmetrical. The desired forward attachment is such that the udder does not separate sharply from the abdomen but extends into it smoothly and as far forward as possible. The ideal rear attachment does not permit the udder to break sharply from the escutcheon, it should extend well backwards between the legs and far upwards on the escutcheon. The udder is characteristically shaped almost rectangular in horizontal cross section. Its floor should be flat with the four teats, of uniform size and shape, located at what may appear to be the four corners. There are frequently considerable variations, however, from this optimum form and attachment.

The blood supplied to the udder passes through the posterior or thoracic aorta, entering the mammary gland through the perineal and mammary arteries (33). Within the gland it is distributed through successively smaller arteries or blood vessels until it comes into very intimate association with the secretory cells. According to Turner, the secretory cells are bathed in blood plasma which passes out of the capillaries to contact them. The venous blood passes from the vicinity of the secretory tissue or the alveoli into venous capillaries, then through the perineal vein, the inguinal canal and the subcutaneous abdominal veins to the heart. The first of these veins continues within the abdominal cavity more or less directly to the heart. The latter veins, sometimes called mammary or milk veins, lie partly outside the abdominal cavity and form ridges which are visible on either side of the abdomen of the cow. These are seen to extend forward, from either side of the forward attachment of the udder, almost to the chest where, with or without branching, they pass through openings, called milk wells, into the abdominal cavity. They continue from here to the heart.

The lymphatic vessels extend from all parts of the glands to the supramammary lymphatic node, located at the base of the udder, from which apparently a single lymph vessel continues on to connect later with the anterior vena cava where the lymph fluid enters the blood stream.

Hormones and Milk Secretion

A hormone is a substance which is formed in one organ but instigates specific physiological activity in another. It is

carried from one organ to the other in the animal body by the blood.

The secretion of milk is initiated principally through the effect of hormones. Those responsible are secreted largely by the anterior lobe of the pituitary gland, but may also come from the ovary or corpus luteum, adrenals, thyroid gland and placenta. The hormones involved in the secretion of milk may be divided into three groups, namely those which are oestrogenic, those which are mammogenic and those which are lactogenic.

The Oestrogenic Hormones

This group includes three hormones. One, referred to as F. S. H., according to Espe (33), is produced by the pituitary gland. It initiates ovulation in the heifer and regulates its periodical appearance thereafter, except as interrupted by pregnancy throughout the greater part of the lifetime of the individual. The other two hormones are produced largely by the corpus luteum in the ovary, although they may also be produced by the placenta. Oestrogen induces heat or oestrus and is directly or indirectly responsible for tubule development in the mammary tissue. It stimulates the production of mammogenic hormones of two sorts by the pituitary. Oestrogen seems to increase during lactation and increasingly retard the lactogenic substances. Progestin is known as a hormone or pregnancy, although this may also be true of oestrogen. This hormone is produced by the corpus luteum which is retained in the ovary during pregnancy. It stimulates the generation of the duct or collecting system of the mammary gland.

The Mammogenic Hormones

These are responsible for the growth and development of the secretory and other closely related tissues, such as the tubes and ducts, of the mammary gland (38). Mammogen is responsible for the growth of the duct system, while another hormone of this group stimulates the growth of the tubule and alveolar system.

The Lactogenic Hormones

The most important of the lactogenic hormones is lactogen, also called galactin and prolactin. This hormone is produced by the anterior lobe of the pituitary and is responsible for the initiation and maintenance of the secretion of milk. For some

unknown reason the production of this hormone is prevented during the first pregnancy. During subsequent pregnancies it is produced but at a rate that diminishes as pregnancy progresses. Its quantity is greatest immediately *post partum*, or after parturition, when the greatest milk flow occurs. A small quantity of this hormone, the masking effect of others or the gradual wearing out or senescence of the alveoli gives rise to a decreasing quantity of milk produced subsequently. The amount of milk produced is closely related to the amount of this hormone in the blood stream. Cortilactin is produced by the cortical tissues of the adrenals. Its part in milk secretion is much like that of prolactin. This hormone seems to be an active form of corticosterone. Thyroxin, from the thyroid gland, increases the quantity of milk as well as the quantity of butter fat.

During pregnancy there is a continued supply of certain hormones, arising in the corpus luteum and placenta, which aid in the development of the mammary gland and which, to a limited extent, cause it to function. As pregnancy advances and parturition approaches, the gland becomes more and more active, apart from its continued physical development. The activity of the gland at this time is indicated by the presence of a milk-like fluid which can be withdrawn in varying quantities, sometimes as early as several weeks but usually only a few days before parturition. The internal changes in the gland which are associated with this preparturient secretion are those described elsewhere in reference to the physical development of the gland and the effect of various stimuli at the time of milking or nursing.

Nervous Control in Milk Secretion

Experiments in which one or more of the main nerves leading to the mammary gland were severed have produced varying effects on the secretion of milk. These effects have involved the quantity and the physical and chemical properties of the milk produced subsequently. They have indicated with some certainty, however, that the gland functions independent of any true secretory nervous fibres. Nerves do, on the other hand, play a part in both the secretion and ejection of milk.

Nerves carry stimuli to and from the central nervous system. Certain stimuli received by this system initiate a number of

physiological processes concerned with the secretion and ejection of milk by the mammary gland. Such stimuli arise from the manipulation of the teats and udder by the calf during suckling or by the man or machine during milking or from other causes, such as certain conditioned reflexes and pregnancy. Conditioned reflexes result from the cow repeatedly associating certain sights or sounds with the suckling of the calf or the milking operation. The sound of or presence of the calf, a familiar call at the usual milking time, the receiving of feed in the milking stall at the usual time and other such things may in time produce a conditioned reflex which initiates the secretion and/or ejection of milk.

Although the results of these various stimuli are not completely understood, they are manifold (33).

There is, firstly, the stimulation of either the formation or secretion of hormones, particularly in the pituitary gland, which are important in effecting the secretion of milk for the duration of a stimulus and during subsequent intervals such as between nursings or milkings.

Secondly, the capillaries supplying blood to the alveoli increase their blood carrying capacity rather quickly, supplying additional quantities of blood to the secretory cells. The result of this may be a possible increase not in the rate of secretion, but in the rate at which the secretory cells eject milk that has been or is being secreted.

Thirdly, the canals of the collecting system of the udder change from rather elongated passages with very narrow openings to somewhat shorter structures with openings of a much larger diameter. They then afford much less resistance to the passage of the milk from the alveoli to the teat cistern. The resulting accumulation of milk contributes to an engorged appearance of the teat and gland or a swollen or enlarged appearance of the udder. The speed with which this action, in particular, occurs, after the manipulation which instigates it, determines how quickly the animal will let down her milk after the milking has begun.

The nerves control the smooth or unstriated muscle tissues in the circulatory, secretory and collecting systems of the gland. This determines the blood supply which reaches the vicinity of the secretory cells, as has already been described. It may also determine the activity of these cells and their capacity in re-

spect to both the volume of milk that may be held at one time and the volume of milk that may be carried by or that may flow through the collecting canals. As the blood holding capacity of the capillaries near and surrounding the alveoli increases, the extra blood produces a pressure. This pressure effects more rapid emptying of the secretory cells of the alveoli, their lumina and the nearby tubules and other collecting passages. This same pressure assists the change in muscle tone in effecting those changes in the collecting system which facilitate drainage. This results in the rapid accumulation of considerable quantities of milk in the milk cistern and its supplying tubes.

Nerves are said to play a part in the permeability of the capillaries supplying blood, carrying the precursors of milk, to the secretory cells. The increased pressure resulting from the engorging of these capillaries with an increased flow of blood in itself facilitates the release of milk by the secretory cells and its movement to the milk cistern. The permeability of the walls of these capillaries would determine, to a considerable extent, the supply of food and raw material in the form of blood constituents, available for further activity of the secretory tissues.

Finally, nerves may play some part in regulating the tension or relaxation of the sphincter muscle at the teat orifice. Two things may cause the cow to be a hard milker; the speed and extent of the whole group of responses to manipulations, for example, may be slow or limited, resulting in the milk coming into the milk cistern very slowly, much slower than it might be possible to withdraw it; or, secondly, the sphincter muscle may be very tight, interfering with rapid removal of the milk.

Manipulation Stimulates the Flow of Milk

At milking time some manipulation of the udder may be necessary, although other reflexes of one kind or another may provide the necessary stimulus, to start the rapid flow or ejection of milk within the udder. The amount of such manipulation required varies widely in different individuals. Cows that are not highly developed genetically as milking animals seem to require a stronger stimulus than those which have for generations been bred and selected for their ability to produce large volumes of milk. Highly developed dairy cattle in the West vary considerably in this respect; it seems, however, that the zebu or buffalo cow of India usually demands more vigorous

stimulation. Whether this is the cause for the general practice of putting the calf with the cow to induce her to let down her milk due to the reflexes that occur because of the calf's presence, or due to the manipulation the calf gives the udder by butting and suckling, or whether the demand for greater stimulus is the effect of the age-old practice of allowing the calf to be with the cow, is questionable. In as much as there are cattle which have not been carefully bred and selected for generations as milk producing animals, but which require very little if any stimulus in this respect, particularly as provided by the calf, it would seem that the practice, which is so widely followed and so firmly insisted upon, of raising the calf by the natural nursing method, can be gradually overcome. Since whatever stimulus the calf can provide is available in other ways, it would seem that the presence of the calf meets only a social need.

By consistently following a standard and uniform procedure in preparing the cow for milking, such as feeding her near the milking time; washing and grooming her in a regular manner; by milking her at a fixed time in the same location or stall by the same man; by milking consistently on the same side; or by other means; habits can be formed which will obviate the need for the psychical or mechanical stimulus provided by the calf. Furthermore, apart from other possibilities, the necessary stimulation can almost always be provided by briefly manipulating the udder with the hands at the beginning of the milking process. Most cows can be taught without great difficulty to let down their milk if by repetition they are brought to associate the milking operation with one or more sensory stimuli, other than those involving the use of the calf.

The Calf is not Required to Stimulate the Milk Flow

Nature has so constructed the nervous system of the female of any mammalian species that the presence of its young and the attempts on the part of its young to suck are no doubt the strongest possible stimulus for bringing about the ejection of milk. Although it is presumed by most persons, in India at least, that the calf alone can provide the required stimulus, this is not always true. Certainly the calf, if it has sufficient strength to stand—or possible when not strong enough to do that, as even the straw-stuffed skin of a dead calf, supplemented with manual stimulation by the milker, is sometimes used—will provide

this stimulation, except in very rare cases in which the cow wilfully refuses to accept the responsibility of motherhood.

Experience has shown, in those herds in India in which weaning is practised, that the removal of the calf immediately after birth, before it has once nursed, is necessary if it is hoped that the cow will produce satisfactorily or to the limit of her ability without her calf under the environmental conditions existing. Most cows which have been allowed their calf for any length of time will be inclined to demand it thereafter before letting down the milk. This would suggest that the need for the calf for this purpose is an acquired characteristic. This seems to be largely true.

There are, however, rare cows whose demand for their calf seems to be an inherited characteristic. This is illustrated by Red Sindhi cow No. 306 at the Allahabad Agricultural Institute. This cow had her first calf taken from her at birth. No calf was allowed with her at any time during that lactation. Her production was 531 pounds of milk in 220 days. She was allowed to nuzzle and lick her second calf at each milking, but never allowed to suckle it. In her second lactation she produced 3896 pounds of milk in 302 days. Her third calf was allowed with her in the same manner as her. second. Her third lactation production was 4406 pounds in 291 days. In her fourth lactation the calf was removed as the first one had been; her production was only 1872 pounds in 156 days. The production of her fifth lactation, when the calf was again removed was only 212 pounds of milk in 68 days. Her veterinary record showed that her production might have been affected by her health in the fifth lactation, but not otherwise. Such cows, however, are encountered only rarely where weaning is a regular practice. In herds in which the practice of weaning is followed, such animals may be discarded to eliminate the disturbances which they cause in the weaning programme.

There seems to be little if any difference between hand and machine milking in the effect it has upon the rate of milk secretion or the total amount secreted in a given period of time. Machines usually remove milk rapidly from the udder, whereas certain hand milkers may remove the milk very slowly. The more rapidly the milk is removed, the better. Machines may, therefore, have certain advantages over hand milking, but the economic considerations in favour of hand milking probably

outweigh any advantages there may be in the use of the machine, so far as conditions in this country at the present time are concerned.

Precursors of the Constituents of Milk

As is explained in Chapter IV, milk contains butter fat, protein, lactose, ash or minerals and vitamins. There are also pigments as well as cell bodies normally present. All constituents of milk, except for certain body and blood cells, are derived from materials which constitute the blood plasma. The blood consists of about 60 per cent plasma and 40 per cent corpuscles; it represents between 6 and 8 per cent of the body weight of the female bovine, depending upon her age (101). It is stated by some authorities that the ratio of pounds of blood which must pass through the udder to pounds of milk produced approximates four hundred to one.

Fat is derived, in a manner which is yet not completely understood, largely from the phospholipids and lecithin in the blood. The secretion of milk fat seems greatest when the secretory cells and alveoli are distended (86). Carbohydrates or a carbohydrate-like material in the blood, are also used in the formation of a small portion of the butter fat (14). The rate at which lipids are removed from the blood during the lactation period is very low at milking time. This rate increases, however, for about four hours thereafter, from which time it remains quite constant until the next milking when it drops rather suddenly. This cycle is repeated between each two milkings.

Lactose is formed by the secretory cells from the blood glucose. It is likely that some glucose is first converted into galactose which is then combined with equal parts of glucose to form lactose.

There are three proteins in milk of which casein constitutes about 75 to 80 per cent. This protein is produced by the breaking down of the proteins, principally globulin, or haemoglobin, of the blood plasma as they are received by the secretory cells. The products of this breakdown are then used in synthesizing casein. Albumen is derived from the blood globulin in a manner similar to that of casein. Lactoglobulin is derived directly from globulin as contained in the blood plasma; no change seems to take place in this case.

All the minerals found in milk come more or less directly from the blood plasma. Only a few of them, however, are changed in the process. Some of them, principally calcium, combine with casein during its synthesis.

All vitamins found in milk come unchanged from the blood plasma.

There are two main pigments in milk; carotene and lactoflavin. Both of these materials are produced from pigments found in the blood, their production being influenced by the heredity of the producing animal and the feeding conditions.

Milk, as drawn from the udder, normally contains numerous blood and body cells. Leucocytes or white blood cells come directly from the blood stream. Some of the secretory cells in the alveoli disintegrate during the process of milk secretion, or from other possible causes, and may pass as fairly complete cells into the milk. During the milking operation the teat and lower part of the udder are subjected to a considerable amount of friction. This wears off numerous epithelial cells from the epidermal layer. These cells drop into the milk, explaining their presence there.

Rate of Secretion and Capacity of the Udder

The major portion of the milk that may be obtained from a cow at one milking is in the udder at milking time. In the past it was thought that most of the milk was produced in the very few minutes during which the animal was being milked. There are two facts which lead to the present opinion that most of the milk is in the udder at milking time. Firstly, the quantity of water alone contained in the milk produced at one milking, particularly in the case of high producing animals, could not be removed from the blood in such a short time without fatal results. Secondly, it is now known that the capacity of the udder is sufficient to hold what milk is ordinarily produced at one time. The milk, therefore, is produced, secreted but probably not completely ejected, at a continuous rate during the milking interval and is stored in the udder.

Rapidity and Number of Milkings

Osmosis is a term applied to the passage of the materials of a true solution, either the solvent or the solute, through a

membrane. Natural membranes may exist as specialized tissues, such as the walls of the blood capillaries, the intestines, the plant roots, or as the walls of individual cells, such as the secretory cells in the mammary gland. Osmotic pressure is that pressure, expressed in atmospheres, required to just prevent the entry of a pure solvent into a solution through a strictly semi-permeable membrane, a membrane which permits passage of the solvent and not the solute. The force with which the particles of a solute attempt to pass through a membrane into a pure solvent is comparable to the pressure just defined. The two may, consequently, be thought of together when osmotic pressure is considered since the movement of materials through membranes in nature involves either the solvent, the solute or both.

Blood and milk are isotonic, that is they have equal osmotic pressures. Such pressure is determined, among other things, by the concentration of material in true solution in a solvent. Hence, the concentration of dissolved materials in true solution in the blood is identical to the concentration of dissolved materials in true solution in the milk. Such materials need not be the same; they actually are not the same in the case of blood and milk. One ion of one material in true solution in water gives rise to a pressure equal to that of one ion of any other material in true solution in water. Therefore, when two solutions of equal concentration of dissolved materials are separated by a membrane, the pressures on either side of that membrane are equal. This is true provided the external pressure to which the two solutions are subjected; the electrical charges of the particles of solutes, the solvents and the two sides of the membrane; and the volume of the two solutions are equal. Other things being equal, if the concentration of solution on one side of the membrane is greater than that on the other side of the same membrane, the pressures are unbalanced. The result is the movement of particles of the solute or of a portion of the solvent from the higher concentration through the membrane to the lower concentration. The solvent tends to migrate from the higher concentration of solvent (the lower concentration of solute) to the lower concentration of solvent (the higher concentration of solute) whereas the solute tends to migrate in the opposite direction or counter current to this, that is from the higher concentration of solute (the lower concentration of sol-

vent) to the lower concentration of solute (the higher concentration of solvent).

The secretion of milk involves, among other things, the passage of water and solid matter in solution, through membranes by osmosis. Water is the solvent in blood and milk. The solutes, or dissolved materials, consist of those materials in the blood which constitute the precursors of milk solids and the solid materials themselves in the milk. The membranes through which they pass are the walls of the blood capillaries and of the secretory cells. As milk accumulates in the udder a non-osmotic or external pressure builds up which tends to offset the migration of the solute or solvent due to osmosis. The more nearly empty the udder, the freer materials are to migrate or the less interference from this cause there is with milk secretion. Immediately after milking, therefore, when the pressure within the udder is at its lowest, the rate of secretion is greatest.

Rapid milking or rapid drainage of the udder prevents the possibility of undue pressure, resulting from the accumulation of free milk therein, increasing to a point at which it may interfere with the ejection of milk at that instance when, as a result of the stimulus of manipulation, or other possible influence, ejection tends to occur at a very rapid rate. Failure to remove milk quickly enough to avoid this may retard the ejection of milk earlier than might otherwise occur, resulting in a smaller quantity being produced, or in a lower production.

In the case of animals which are heavy milkers, those which produce large volumes of milk, frequent milking is advantageous. Following any one milking, as has been explained, milk secretion proceeds at a rather rapid rate at first, but a rate which diminishes subsequently as the pressure of the accumulated milk in the udder increases following milking. The greater the volume of milk produced, the quicker the accumulation of milk produces a pressure which tends to have a retarding influence on the rate of milk secretion. Advantage may be taken, in the case of heavy producers, of the more rapid rate of secretion following a milking by emptying the udder very frequently. This is shown by the fact that the total yield over a period of time, either a day or lactation for example, may be 25 per cent more on four milkings a day than on two. The increase may be 10 to 20 per cent on three milkings a day as compared to two milkings (30). As the producing capacity of the cow diminishes,

the response that will result from more frequent milking also diminishes until, in the case of poor milkers, that is, those perhaps, which give less than one thousand pounds of milk in 300 days, the value of more frequent milking in terms of higher production practically disappears.

CHAPTER IV

THE CONSTITUENTS OF MILK AND ITS NUTRITIVE VALUE

Milk is a food provided by nature for the young of certain animals. Those animals which produce milk are known as mammals and possess one or more mammary glands in which the milk is secreted. The use of the milk from animals other than man as a human food is an extremely ancient practice. Although some countries, such as Japan, China, Thailand and possibly others, do not yet accept milk as the valuable food it actually is and may therefore be called milkless countries, most countries use considerable quantities of milk and milk products. People in many western countries consume an average of between 30 and 40 ounces of milk, or its equivalent in the form of milk products, daily per capita. Finland consumes considerably more than this, or about 63 ounces, according to Dr. Wright (113), whereas India consumes only about 5·8 ounces (18). In spite of this very low consumption. India is not a milkless country, for the annual production of milk is second largest in the world, being excelled only by the United States of America. The tremendous human population of this country requires many times the amount of milk now available, which is almost 750,000,000 maunds or 27½ million tons per annum (18), to provide an adequate supply for everyone.

Milk is defined in various ways, depending usually upon the use to which it is to be put, or other possible considerations. Three definitions to illustrate this may be given: 1. Milk is the normal secretion of the mammary glands of mammals (31); 2. Milk is the fluid which is drawn from a perfectly healthy udder of a perfectly healthy cow living under the most favourable sanitary conditions (42); 3. Milk is the lacteal secretion obtained by the complete milking of one or more healthy cows, excluding that obtained within 15 days before and 5 days after calving, or such longer period as may be necessary to render the milk practically colostrum free; which contains not less than 8 per cent milk solids-not-fat, and not less than 3¼ per cent milk fat (81).

The milk of every mammalian species contains the same constituents, although they occur in different proportions. The composition of milk from several different mammals is given in the table below. Among the solid constituents, fat shows the greatest variation. Since fat contributes about 2·25 times as much heat energy or food energy, expressed in Calories, per unit weight as is provided by carbohydrates or proteins, the large variation in the proportion of fat present in milk is significant in comparing the food values of these different kinds of milk.

THE COMPOSITION OF MILK FROM SOME MAMMALS OTHER THAN THE ZEBU AND BUFFALO.

(Figures show per cent.)

	Species		*Water*	*Fat*	*Sugar*	*Casein*	*Other Protein*	*Ash*
1.	Human (21)	..	88·50	3·30	6·80	0·90	0·40	0·20
2.	Goat (1)	..	86·88	4·07	4·64	3·76		0·85
3.	Sheep (21)	..	79·46	8·63	4·28	5·23	1·45	0·97
4.	Camel (21)	..	86·57	3·07	5·59	4·00		0·77
5.	Mare (21)	..	90·68	1·17	5·77	1·27	0·75	0·36
6.	Reindeer (21)	..	68·20	17·10	2·08	8·40	2·00	1·50
7.	Llama (21)	..	86·55	3·15	5·60	3·00	0·90	0·80
8.	Elephant (21)	..	67·85	19·57	8·84	3·09		0·65
9.	Cat (21)	..	81·63	3·33	4·91	3·12	5·96	0·58
10.	Dog (21)	..	75·44	9·57	3·09	6·10	5·05	0·73
11.	Porpoise (21)	..	41·11	48·50	1·33	11·19		0·57
12.	Ass (2)	..	91·56	0·62	6·10	1·39		0·28

MILK FROM DIFFERENT MAMMALS AS HUMAN FOOD

Because the food value of milk varies with its chemical composition, public health departments define milk in terms of its composition to assure its value as a food always being above a certain minimum. This minimum is generally determined by carefully studying the milk found in the market or markets of the area under the jurisdiction of the department concerned, or by a study of the milk found in all the markets of a particular country.

The milk of many mammals is used for human food purposes in different parts of the world. In India, for example, both the

zebu and the buffalo are important in providing milk for human consumption. The milk of the goat, of the sheep and, to a limited extent, that of the camel and the ass, is also used. Goat milk is used in most parts of the country in small amounts, constituting about 3·1 per cent of the total for the country as compared to about 50·9 per cent provided by the buffalo and 46·0 per cent by the zebu (18). No estimate is available of the amount of milk from the sheep, camel or ass used as a human food in India. The use of milk from the camel is confined particularly to the north-western parts of India, while the milk of the ass is used largely in the Kathiawar and Cutch areas (18). Sheep milk is used more widely than that of the ass or camel; its use is confined largely to the hill and grazing areas where large flocks of sheep are to be found.

Outside of India the zebu is found in parts of Africa where it seems to be indigenous, and in other parts of the world, such as South America, Australia and elsewhere, into which it has been imported; the buffalo is found in the Pacific islands, Malaya, southern Africa and elsewhere. Wherever these milk producing animals are found their milk is used, in some case much more than others, as a human food. The goat is particularly important for supplying milk in Arabia, Spain, southern Europe and Latin America. Sheep milk is used in comparatively large quantities in southern and central Asia and south-eastern Europe. The milk of the camel is relatively important in Arabia and Egypt. In Lapland, Finland, Greenland, Iceland, Alaska and parts of northern Canada the milk of the reindeer is used because of the absence of other species. In Russia and central Asia the mare is used to supply milk for use by the peasantry. It is probable that there are places where still different species of mammalia are used to supply milk for human use, such as the llama in the Andes mountain areas of South America.

The Composition of Milk

The constituents of milk include each of the five main groups of food materials, besides water. These are fats, carbohydrates, proteins, ash or minerals and vitamins. The dairyman frequently divides these materials into two groups, *viz.*, fat and solids-not-fat (commonly written S. N. F.), or he may group them together as total solids (written T. S.). Nutritionists or

dietitians, on the other hand, more commonly consider each of them separately and may further divide each one into its component parts.

The component parts of milk are numerous. Davies (21) lists nearly one hundred different chemical compounds found in milk. For our purpose, however, we shall consider the five groups of food materials as found in milk, with limited subdivisions of each. So far as the milk of the zebu and of the buffalo in this country is concerned, the most comprehensive study of its composition was made at the Agricultural Institute, Allahabad, under a grant from the Indian Council of Agricultural Research. The results of this study are given on page 55 (97). The table on page 56 summarizes the results of this and several other studies of the composition of milk in this country and elsewhere.

Factors affecting the Composition of milk

The chemical composition or the proportion of different constituents in milk varies considerably, as shown by the tables which follow, from species to species and from breed to breed. There are, in addition, numerous other factors that are responsible for variations in the composition of milk. Several of these factors may be discussed in some detail.

Age.—Older animals give milk containing less fat than younger animals. The difference is small, however, as is indicated by Sommer (93), who states that the fat percentage of the milk of a cow in her ninth lactation is about 94·5 per cent as high as it was at maturity. All other constituents probably decrease very slightly, except albumin nitrogen, with advancing age.

Physical Condition and Size.—Large cows within a particular breed frequently give more milk than small cows, but it is not always produced more economically. In general, the greater the quantity of milk, the lower the percentage of fat, although there may be a larger total quantity of fat produced. The cows holding world's records for fat production, for example, are not infrequently of the Holstein-Friesian breed whose average fat content is somewhat below that of most breeds, that is about 3·6 per cent. The other constituents remain practically unchanged with the possible exception of the fat, immediately after parturition. If the cow is in good physical condition and slightly fat at the time of parturition there may be a slightly higher fat content in the milk for as long as three months there-

SUMMARY OF THE COMPOSITION OF MILK AT THE ALLAHABAD AGRICULTURAL INSTITUTE, 1936 TO 1939. (FIGURES SHOW MEAN PER CENT.)

	Zebus				Buffaloes		
	Red Sindhi	Village Zebu	Holstein-Sindhi	Average	Murrah	Village Buffalo	Average
Total Solids	13·444	14·302	12·538	13·449	16·407	17·002	16·774
Fat	4·925	5·607	4·420	4·968	7·161	7·624	7·446
Solids-not-fat	8·497	8·702	8·079	8·460	9·215	9·386	9·321
Lactose	4·584	4·786	4·393	4·589	4·809	4·924	4·880
Ash	0·7516	0·7249	0·7349	0·7433	0·7652	0·7892	0·7800
Phosphorus Pentoxide	0·2351	0·2187	0·2070	0·2272	0·2735	0·2794	0·2770
Calcium Oxide	0·2112	0·2005	0·1883	0·2051	0·2490	0·2664	0·2592
Chlorine	0·0831	0·0795	0·1113	0·0883	0·0671	0·0645	0·0655
Crude Protein	3·208	3·312	2·934	3·178	3·768	3·797	3·784
True Protein	2·855	3·013	2·501	2·789	3·350	3·413	3·386
Casein	2·419	2·602	2·128	2·380	2·983	3·016	3·003
Albumin	0·415	0·392	0·381	0·402	0·361	0·401	0·383
Non-Protein Nitrogen	0·0548	0·0503	0·0558	0·0542	0·0543	0·0479	0·0507
Water*	86·556	85·698	87·462	86·551	83·593	82·998	83·226
Specific Gravity	1·03088	1·03104	1·02950	1·03066	1·03122	1·03156	1·03143
Freezing Point Depression**	0·5454	0·5492	0·5410	0·5455	0·5429	0·5424	0·5426

* *Calculated for this table*

** *Degrees below zero Centigrade; hence* 0·5454 *equals*—0·5454° *C.*

THE COMPOSITION OF MILK OF SOME ZEBU, TAURUS AND BUFFALO BREEDS. (FIGURES SHOW PER CENT.)

Species and Breeds	*Water*	*Fat*	*Protein*	*Lactose*	*Ash*	*S. N. F.*	*T. S.*
ZEBU—							
Gir (64)	..	5·70*	..	..	..	..	..
Montgomery (61)	..	4·23	..	..	..	..	..
Scindi (89)	..	4·65*	..	..	..	..	13·32*
Ongole or Nellore (91)	..	4·68	..	..	..	..	..
Kankrej (57)	..	4·18*	..	..	..	8·66*	..
Hariana (58)	..	4·595	..	..	..	..	..
Tharparker (58)	..	4·553	..	..	..	..	..
Red Sindhi (97)	86·56	4·92	3·21	4·58	0·75	8·50	..
BUFFALO—							
Murrah (97)	83·59	7·16	3·77	4·81	0·76	9·22	..
Surti (65)	..	8·4*	..	..	..	..	18·75*
Murra (90)	..	7·12	..	..	..	..	..
TAURUS—							
Jersey (21)	85·27	5·14	3·80	5·04	0·75	9·59	..
Ayreshire (21)	87·10	3·85	3·34	5·02	0·69	9·05	..
Shorthorn (21)	87·43	4·63	3·32	4·89	0·73	8·94	..
Friesian (21)	88·07	3·45	3·15	4·65	0·68	8·48	..
Welsh (42)	85·85	4·91	..	..	..	9·24	..
Dutch (42)	87·60	3·75	..	..	..	8·65	..

**Average of morning and evening milk.*

after, although underfeeding is claimed as being necessary to show this (33).

Exercise.—Exercise causes a very slight increase in the percentage of fat, together with a slight decrease in the quantity of milk. Although exercise aids digestion, the stimulus to greater milk flow which results is overcome by the rquirement of greater amounts of energy for exercising. This leaves less energy for milk production. It is unwise, however, in attempting to prevent such a decrease in the flow of milk, to allow too little exercise. A minimum of exercise daily is imperative if the milking animal is to carry out her milk producing functions properly.

Individuality.—The fat percentage in the milk of a cow is an inherited character. It is thus characteristic of the individual, other things, such as health and feed, being normal and adequate. Similarly, the mineral content seems to be characteristic of the individual animal. The percentages of protein and lactose also vary with the individual, apart from other possible causes. A low lactose content is always accompanied by a high chlorine content.

Health.—The question of health may, for our purpose, be divided into two parts. Diseases of a general nature affect the composition of the milk differently in many respects from diseases which specifically involve the secretory tissue, such as mastitis.

Diseases of a general nature reduce the amount of milk. This is accompanied by slight increases in the fat and other solid constituents, except casein and lactose. The most marked changes are a decrease in the lactose and an increase in the chlorine content, making the milk slightly alkaline. The pH of such milk is about 7·0, whereas the pH of normal milk is about 6·7. The freezing point depression and the osmotic pressure remain the same.

Mastitis causes a marked increase in the chlorine content and a decrease in the lactose. The fat percentage decreases, although there is a decrease rather than an increase in the amount of milk produced. There is a slight increase in proteins other than casein. With chlorine, the sodium and the total ash likewise increase, whereas potassium, phosphate, magnesium and calcium decrease slightly. There is an increase in non-protein nitrogen.

Oestrus.—The normal cow experiences periodic sexual excitement. This is known as oestrus or heat. At this time the animal is very restless and may be extremely nervous, thereby consuming considerable amounts of energy for one or two days. During this time the milk flow is usually reduced, frequently considerably. This reduction is a result of the utilisation of energy for purposes other than the production of milk and of failure to let down the milk. The latter seems to be the more important reason for the smaller milk flow at this time. As is explained elsewhere, the major portion of the fat produced at any one milking is found in the strippings. Milk which is withheld by the cow is largely strippings. The result of withholding the milk is a fat content somewhat lower than normal. It is reported that the fat percentage of the milk of one cow dropped to between 1·6 and 1·8 per cent on breeding (42). There seems to be no evidence available that would indicate that the solids-not-fat content of the milk at this time changes appreciably.

Stage of Lactation.—The lactation period for most animals may be divided into three stages, so far as variation in the composition of the milk is concerned : 1. Immediately after parturition a special type of milk called colostrum or beestings is produced. This continues for only a few days, usually three to five but sometimes as long as ten days, with the character of the milk gradually changing to that of normal milk. 2. During the major part of the lactation, milk of a normal composition, health and other conditions permitting, is produced. This period may extend to between six and twelve months, normally about ten, after parturition. Those animals which go dry during this time do not ordinarily produce milk of a composition that would indicate they have entered the third stage. 3. Beyond the second stage is that of an extended lactation when minor changes occur in the physical and chemical properties of the milk.

Colostrum is reddish-yellow in colour, has an abnormal odour, a bitter taste, is very slimy and viscous, is decidedly acid in reaction and has a low heat coagulation point or coagulates easily on heating. The composition of this milk is very different from that of normal milk, particularly during the first few hours after calving, but rapidly changes to normal within 3 to 5 days, depending upon the speed of recovery of the cow. The water, lactose, fat and sometimes the casein content is

lower, whereas the total solids, ash, albumin, globulin, non-protein nitrogen and sometimes the casein are higher than in normal milk. The greatest difference between this milk and normal milk is the globulin content which may be 12 to 15 times as high as normally. The iron content is also comparatively very high, while total ash may be as high as twice the usual amount. Such milk contains a high antibody titre. Such antibodies protect the calf from *Bacillus coli commune*, according to Van Es (105). The composition of colostrum from certain cows in this country is given in the following table.

THE COMPOSITION OF COLOSTRUM OF THE ZEBU AND BUFFALO

(Figures show per cent.)

	T. S.	*Fat*	*Sugar*	*Total Protein*	*Casein*	*Albumen*	*Globulin*	*Ash*
Montgomery (3) ..	22·55	4·6	3·30	13·22	4·56	8·70		1·23
Red Sindhi (88) ..	18·2	2·0	2·2	12·8	4·0	2·6	6·2	1·0
Murrah (88) ..	28·9	3·9	2·2	21·4	6·8	3·8	10·8	1·1

The discussion which constitutes the major portion of this chapter applies to the milk produced during the second stage of the lactation. During this period, as a whole, the fat percentage varies inversely as the quantity of milk. The minimum fat percentage occurs sometime before the fourth month, for it is generally within the first three months that the maximum milk flow is attained. The fat globules gradually become smaller and the proportion of unsaturated fatty acids in the butter fat increases. The Ca : P ratio increases as lactation advances. The use of the term normal to distinguish milk produced in this stage of the lactation is actually a misnomer, for colostrum is perfectly normal milk for that particular stage of the lactation. It is a convenient term, however, as the milk of commerce is largely that produced at this time. This fact may be considered as justifying this usage.

During the stage of extended lactation, varying from between the tenth or/and twelfth month for most cows up to the end of the lactation, which has been known to continue as long as 30 months (52), changes occur in the composition of the milk that are characteristic of this period. The quantity of milk diminishes

with accompanying increases in the percentage of most constituents, except lactose which may or may not decrease. The greatest increases are in the fat and chlorine. The pH, and enzyme, particularly catalase, values increase, while the size of the fat globule decreases. Changes in the composition of the butter fat, such as a decrease in the volatile acid content, become more pronounced. The flavour of the milk during this period becomes less desirable, even becoming bitter, due to the lower or at least comparatively lower lactose and higher ash, particularly the chlorine.

Variations from Milking to Milking.—For reasons as yet apparently unknown there are variations in the composition of the milk of any cow from day to day and from milking to milking. These variations, which are usually small, almost exclusively involve the butter fat. According to Davies (21), the variation from milking to milking is at a minimum where the intervals are the same, although the amount of milk in the morning will be greater than in the evening on two milkings a day. He adds that for each hour the interval exceeds 12 hours the fat percentage is lowered from 0·10 to 0·15 per cent; for each hour the interval is less than 12 hours the fat increases 0·20 to 0·25 per cent. On three time milkings the quantity of milk is more uniform but the fat still varies noticeably.

Cows are inclined to rest more during the night, than during the day when the effect on the composition of milk of considerably more exercise is noted. With the higher quantity of milk that results from less exercise, among other possible causes, the fat percentage is reduced. One other factor that may operate at night is that of atmospheric temperature, which is discussed later.

Stage and Completeness of Milking.—The milk drawn from the udder of the milking animal during a single milking may be divided into three parts, *viz.*, the fore milk, or the first few streams; the middle milk, or the major portion of the quantity given during the milking; and the strippings, or the last several streams from each quarter of the udder after the flow noticeably diminishes.

The solids-not-fat content of the milk of these three different stages is practically the same, any changes usually being small. The fat content, on the other hand, varies rather considerably,

starting comparatively low in the fore milk and increasing as the milking progresses until in the strippings the fat percentage may be two or three times the average for the milking as a whole. As the yield increases this variation in the fat percentage increases.

Incomplete milking or inefficient stripping involves, fundamentally, the removal of only the fore milk and the middle milk, leaving all or a good portion of the strippings in the udder. The first result of this practice is a reduction in the quantity of milk. Since the highest fat content is in the strippings, this is obviously accompanied by a reduction in the percentage, and consequently the quantity, of fat. This fact may be illustrated by the following rather simple calculations:—

Stage of milking	*Amount of milk*	*Per cent of fat*	*Amount of fat*
	lb.		lb.
Fore milk ..	1	2·0	0·02
Middle milk ..	8	4·0	0·32
Strippings ..	1	10·0	0·10
Total ..	10	4·4	0·44
Total excluding strippings ..	9	3·7	0·34

According to workers at the University of Missouri, milk left in the udder tends to suppress the rate of milk secretion earlier during the next milking interval and eventually hasten the decline in the flow of milk during the lactation. This results in the animal drying off earlier than might otherwise be expected (102).

Feed.—The butter fat content of milk, since it is an inherited characteristic, cannot be appreciably altered by special feeding. Those changes in the percentage of butter fat that are brought about by special feeding are only temporary, the composition of the milk in this respect returning to normal rather soon even on continued special or irregular feeding. Changes in the feed will effect the quantity of milk primarily; any changes in the fat percentage being largely those which are normally

expected to accompany changes in the amount of milk. A starvation diet, however, reduces the fat slightly while reducing the quantity of milk considerably. In some cases excessive feeding of a balanced ration causes a reduction in the fat percentage, while in others the fat may increase. Feeding excessive amounts of fat or of protein may cause increases in the fat content of the milk of as much as 0·2 per cent in the former case, but such changes, as has been indicated, are not permanent; they do not continue even so long as the excess fat or protein is continued in the ration.

Certain types of fats and oils in the feed will, however, change the composition of the butter fat noticeably. Such materials as coconut and cottonseed oils will cause a higher proportion of the high melting point fatty acids to appear in the butter fat, resulting in what is known as hard fat, which refers to the physical condition of the butter fat at ordinary temperatures. Having an average melting point for the composite fat, as a consequence of this change in chemical composition, that is higher than normal, the fat is harder than otherwise at the temperatures usually used in the making of butter. Linseed oil softens the fat by changing the proportion of fatty acids in the butter fat to a high proportion of the low melting point fatty acids. This brings the average melting point of the composite fat nearer to the temperatures usually encountered in handling cream, butter and ghee, giving a softer fat at those temperatures.

Feeding may indirectly affect the fat content of the milk by producing a good physical condition in the animal with some fatness at parturition. The affect of this condition on the fat content of the milk has already been discussed.

Underfeeding causes a decrease in the lactose content of milk which the animal produces; overfeeding causes an increase. The change in either case is not more than about 0·5 per cent. Changes in the source of carbohydrates in the ration cause no changes in the lactose content of the milk, provided the heat energy available is sufficient to meet the normal requirements in all cases. Changes which occur in the lactose content of milk are always accompanied by converse changes in the chlorine content; that is, when the lactose increases the chlorine decreases, and vice versa.

The vitamin A content of milk increases with an increase in the proportion of green feed in the diet. Cows, it is said, get

over 90 per cent of their vitamin A requirements from the beta-carotene contained in the roughage feeds. The vitamin B content of milk is quite constant, varying only slightly, if at all, as a result of variation in the intake of this vaitamin in the feed. Roots and green succulent feeds cause increases in the content of vitamin C in milk, but the variations are small. According to Davies (21), the variation is from slightly less than 2·2 milligrams of ascorbic acid per 100 millilitres of milk on dry and unsucculent feeds, to 2·5 milligrams when the cows are fed on succulent and green feeds. Green grasses contain very little vitamin D, while certain feeds, with or without special preparation by ultra-violet irradiation or in other ways, such as the addition of cod-liver oil or irradiated yeast, are very high in this vitamin. The vitamin D content of milk depends upon the quantity of this vitamin in the feed ingested and the extent of exposure of the producing animal to sun light. Little if anything is known of the effect of feeding on the vitamin E content of milk.

The results on the composition of the milk of feeding different minerals vary so much that reports are contradictory. Feeding excessive amounts of sodium chloride or ordinary salt seems to have no effect. The effect on the composition of milk of changes in the intake of calcium or phosphorus are not consistent. A greater quantity of calcium per unit of phosphorus or a wider calcium: phosphorus ratio in the feed increases the requirements for vitamin D which is necessary for the utilisation of calcium. Reports are again contradictory as to the need for vitamin D in the deposition of calcium in milk during its secretion; calcium must be assimilated by the body with the help of this vitamin, however, before it would be available to appear in the milk. There is a loss of body calcium, possibly also of other minerals, at the peak of a lactation as a result of the fact that body reserves may be utilized to prevent changes in the mineral content of milk. Although the calcium oxide content of milk does not change noticeably with changes in the intake of calcium, the coagulation on the addition of alcohol seems to take place more readily, as does coagulation with rennet. None of the other mineral constituents of the milk can be noticeably altered by change of feeding practices, except citric acid and iodine. Citric acid in the milk may increase about 0·03 to 0·06 per cent when cows first start feeding on fresh green grass or fresh pasture, according to Sommer (93). This may occur at

the beginning of the monsoon season in this country. Iodine may be increased several fold in the milk by increasing the iodine intake, with such changes in the milk continuing so long as the higher intake continues.

Season.—No work has been done to determine the effect in India, if any, of variations in the seasons of the year on the composition of milk. Data of this sort available in western countries do not apply fully to our conditions because of the temperature and rainfall pattern variations from season to season there as compared to those we find in our country. In the United States, for example, there are seasons in most parts of the country which are locally known as rainy seasons. The temperature prevailing during those periods, their duration and the rainfall pattern differ considerably, however, from the monsoon with which we are familiar. Considering the quantity and quality of green feed available there with that available in India in the respective rainy seasons, the effect on the composition of milk may be somewhat the same. Again, the hot dry season of May and June in northern India is somewhat comparable to July and August in the Great Plains region of North America. The heat is very much more intense, and the humidity probably less here than in that area, but the effect on the feed conditions, so far as natural grazing is concerned, is much the same in the two places. The winter season of the American Great Plains is much more intense than anything most of India experiences, except in the remote Himalayan regions. Again, India's long and pleasant winter season can be compared to only a very short season in the North American area in the fall of the year.

Espe (33) states that the environmental temperature causes variations in the fat content of the milk that are inversely proportional to the temperature. Sommer (93) says that the solids-not-fat content of the milk declines during July and August in the United States (possibly May and June in India). Eckles, Combs and Macy (31) indicate a possible variation of up to 0·5 per cent in the fat content due to season. Davies (21), in England, reports that drought conditions may cause appreciable variations in milk composition; he lists three causes of this, *viz.*, insufficient water, irritation by insects and the physiological necessity of secreting a liquid lower in calorific value to suit the naturally smaller need of a potential suckling during hot weather.

The Nutritive Properties of Milk Constituents

Butter Fat

Butter fat, like all fats and oils, is a mixture of several triglycerides of fatty acids, each of which contains an even number of carbon atoms. There are usually nine, but sometimes eleven, fatty acids listed as constituting the major portion of this fat. Other such acids as well as related products are present, although they are of much less importance. Each triglyceride molecule in butter fat is made up of a glyceride radical or portion and three fatty acid radicals which are rarely if ever of the same acid; usually two or three different fatty acids are involved. Of the fatty acids in butter fat, oleic and linoleic are listed by Davies (21) as essential to life in young animals.

Different authorities give different figures for the digestibility of butter fat. These figures vary between 94·4 and 97·2 per cent, according to Sommer (93). Approximately 9 Calories of food or heat energy are provided in each gram of digestible fat. Fat alone accounts for about 55 to 60 per cent of that of the buffalo. Butter fat is present in milk in the form of minute globules measuring between 0·1 and 10·0 microns, averaging about 3·0 microns, in diameter. The size of the globules varies with the breed, age, and health of the cow, her stage of lactation and the kind of feed she is getting. The smaller the fat globules the greater the surface area of the fat that is exposed to the digestive fluids in the human body and therefore, other things being equal, particularly the composition of the fat, the more rapid and presumably the more complete the digestion. The size of the fat globule is likewise of some significance in some of the manufacturing processes; these are discussed elsewhere. Butter fat melts at about 30°C., varying from 28·4° to 36·0°, and solidifies between 19·0° and 24·5° C. (21 and 47). Fat is immiscible with water or skim milk. It is present, therefore, as a colloidal emulsion of minute globules in the non-fat or serum fraction of the milk.

Milk Sugar or Lactose

Milk contains one principal carbohydrate, a sugar known as lactose. It is present in milk in true solution. From 17 to 40 grams of this sugar will dissolve in 100 millilitres of water, the solubility increasing within this range with increasing tempera-

ture. It is insoluble in ether, alcohol or chloroform. Lactose crystals are rhombic prisms. The sugar may be prepared in three forms, the monohydrate, the alpha-anhydride and the beta-hydride, of which the first is the lactose of commerce. The commercial hydrate has the composition $C_{12}H_{22}O_{11}$-H_2O and may contain other milk solids in traces. In crystalline form this sugar is colourless. It is only about one-sixth as sweet to the taste as sucrose or ordinary cane sugar. Its comparatively low solubility causes crystals of lactose to retain their identity in the mouth a little longer than is true of other sugars, giving a sandy feeling on the tongue. This may be particularly noticeable in certain samples of condensed milk or *khoá*.

Lactose is considered to be practically 100 per cent digestible in the human body. It provides approximately 4 Calories of food energy per gram, constituting about 25 per cent of the food energy value of the milk of the zebu and 20 per cent of that of the buffalo. This sugar is known to pass into the lower part of the large intestine, beyond the ileo-caecal valve, almost unchanged and supply nourishment to non-putrefactive bacteria, *Lactobacillus acidophilus*, found there. It is known to have definite stimulating effects on growth in young animals. Much is unknown, however, about the particular characteristics of lactose which cause these special effects.

Although lactose has been reported to have been found in one or two species of fruits, this is questioned by most workers. It does appear in the milk of all mammals. Only extremely small traces of other sugars or carbohydrates are found in milk.

Milk Proteins

The protein substances found in milk are casein, albumin and globulin. Some workers claim the presence of small traces of other minor proteins, although this does not seem to be widely accepted. Casein is present in the form of a colloidal suspension of calcium caseinate and is generally considered the specific protein of milk. It is not found in appreciable amounts if at all elsewhere, whereas albumin and globulin are both found in blood as well as in other biological materials. All proteins are made up of combinations of several amino acids into which they are divided during digestion before they can be assimilated. Some of these amino acids are considered essential to life in young animals. Of the amino acids present in casein and albumin at

least three are essential. According to Jones (48), these are tryptophane, histidine and lysine; they constitute about 10 to 12 per cent of the milk proteins (21). One reason for the importance of milk to life, especially in the young, therefore, is obvious.

Milk proteins are considered to be between 91·7 and 94·3 per cent digestible (93) and to provide about 4 Calories of food energy per gram of digestible protein. They provide about 17 per cent of the food energy value of the milk of the zebu and about 15 per cent of that of the buffalo. Like other proteins, they are coagulated by enzymes, acid, alcohol or heat. In the stomach, therefore, milk proteins form a curd which gives body or firmness to the milk, enabling the peristaltic action of the stomach and the intestines to handle the curd portion of milk as a semi-solid food material rather than as a liquid food. This facilitates passage of this and other materials through the digestive tract.

The firmness of the curd produced under standardized conditions of coagulation has been used as an index to the utility of the proteins of milk as food proteins. Individual breed and species differences in the curd character, curd tension or curd firmness under the same coagulating conditions are known to exist. In cases in which the curd becomes extremely firm, it is compact or tightly formed, thereby preventing the penetration of the digestive fluids to the interior of the curd mass. This results in slower digestion because of the smaller curd surface with which these fluids come into contact. The structure and compactness of soft curds permits digestive fluids to penetrate deeply into the curd mass giving these fluids contact with a very great surface area of the curd. This brings about relatively rapid and complete digestion and avoids, to a large extent, the formation of certain undesirable or toxic materials that might otherwise be formed, in cases in which the digestive system is pre-disposed to do so.

Ash or Minerals

About 0·75 per cent of the milk of the zebu or of the buffalo is mineral material which is left after the incineration of milk. Milk ash includes calcium, sodium, potassium, magnesium, manganese, iron, copper, phosphates, chlorides, iodine and other substances. Some of these occur only in traces. All are present

in the milk as salts in which form they constitute about 0·90 per cent of the milk. The salt which is present in the greatest amount is calcium citrate, followed by potassium di-hydrogen orthophosphate, sodium chloride and others (21).

Minerals found in milk do not provide food or heat energy as do fats, carbohydrates and proteins. They are, nevertheless, essential in nutrition. Those considered essential to life are named above. Of these, some are in milk in a soluble form and some in an insoluble form. Those which are considered to be present in the form of a true solution are sodium, potassium and chlorine; those which are only partly in solution and partly in suspension are calcium, magnesium and phosphate. In the incineration of milk organic materials closely associated with mineral materials, such as citric acid, disintegrate; this accounts for the percentage of ash in milk being slightly less than the percentage of salts.

Vitamins

Several vitamins are present in milk. Some are found in quantities considered very large, while others are found only in traces. Of those present, A, D and E are fat soluble; B_1, B_2 and C are water soluble. As might be expected, therefore, except as the processes involved might destroy them, butter fat and products in which there is a concentration of this fat, such as butter and ghee, are sources of large quantities of the fat soluble vitamins, whereas whole milk, skim milk, butter milk and whey are sources of those which are water soluble. As was true of minerals, vitamins are definitely necessary for proper nutrition although they do not provide heat energy.

The vitamin A content of the milk, found entirely in the fat, depends upon the presence of this vitamin in the feed. This vitamin is heat stable.

Milk is only a fair source of B_1 the anti-neuritic vitamin. This vitamin is heat labile, particularly in the presence of moisture.

Vitamin B includes several other factors such as riboflavin, nicotinic acid, pyridoxine and others. Riboflavin, said to be the growth promoting factor of this vitamin, is found in milk in liberal quantities; nicotinic acid, the anti-pellagra factor, occurs in milk in only small quantities; pyridoxine is also present in rather small quantities. Riboflavin, called lactoflavin when

derived from milk, is heat stable when acid or neutral, but breaks down quickly when alkaline or when exposed to light. Nicotinic acid is very stable to acids, alkali and heat. Pyridoxine is destroyed by light.

Vitamin C, which prevents scurvy, is now known as ascorbic acid because of its anti-scorbutic properties. Ascorbic acid is usually present in milk to the extent of about 2·0 to 3·0 milligrams per 100 millilitres; the amount may go below 2·0 milligrams per cent when green feeds are not available. Buffalo milk is reported to contain slightly more vitamin C than zebu milk, and evening milk more than morning milk (107). This vitamin is very easily destroyed by heat in the presence of air or copper.

The quantity of vitamin D found in milk depends almost entirely upon the vitamin D content of the cow's diet, particularly the amount of green feed it contains. Vitamin D is sufficiently stable to heat to survive pasteurization and even sterilization as usually applied to milk products. It is not easily oxidized.

Vitamin E, the anti-sterility vitamin, is found in milk in small quantities. It is heat labile, that is, heating destroys it.

The Effect of Heat on Milk

The heating of milk produces changes in its physical, chemical and nutritive properties most of which are proportional to the temperature and the duration of the treatment (95). Many effects of heating are only evident after prolonged heating at very high temperatures.

Milk sugar may carmelise to give the milk both a carmel flavour and a brown colour; the odour of freshly heated milk may be slightly different from that of fresh milk due to volatile substances liberated during heating; a cooked flavour may be produced; without agitation a skin may form on the surface of milk while hot as a result of denaturation of proteins at the air/milk interface (95).

Little if any chemical change in the fat results from heating; the principle physical effect is the interference with creaming, so essential in the formation of the cream line in bottled milk. Fat globules rise in milk at a rate which is dependent upon such

factors as their size, the viscosity of the non-fat fraction of milk, the salt content of the milk and the acidity. Fat globule clumps rise faster than individual globules since they act somewhat as larger globules. Maximum creaming results from heating milk to 143°F. for 30 minutes; exposures greater than this greatly reduce cream volume; rapid cooling to a temperature of 45°F. or lower after holding pasteurization increased cream volume (4).

The heating of milk causes the albumin and globulin of milk to coagulate (95). A small portion, about 5 per cent, of the albumin is coagulated at 145°F. for 30 minutes while 82 per cent is coagulated at sterilization temperature (93). The casein is not changed by heating at the two exposures just mentioned. Such a heat treatment does, however, affect the susceptibility of casein, present as calcium caseinate, to coagulation by acid or rennet. Milk heated to 162°F. for 30 minutes, for example, does not coagulate with rennet (43). No appreciable changes of the distribution of nitrogen among the different constituents, except for albumin, was found in milk heated to 239°F. (115°C.) as compared with the fresh raw milk (95). It is questionable, therefore, whether ordinary heating, including brief boiling, alters the food value of the casein of good quality milk. The protein of milk apparently plays a part in the production of a brown colour in milk heated to sterilization temperature (4). The physiological availability of milk protein is not altered by pasteurization (95).

Heating precipitates a part of the colloidal calcium hydrogen phosphate and decreases the soluble phosphate content about 26 per cent at 140°F. for 30 minutes ; the precipitation of calcium on heating varied from 0·35 to 9·75 per cent between temperatures of 140°F. and 180°F. for 30 minutes; some losses of the citrate and iodine of milk occurred on pasteurization by the holding method (95). Hot milk will dissolve greater quantities of certain metals commonly used for dairy equipment than will cold milk.

The titratable acidity of milk first diminishes, due to the driving off of carbon dioxide gas, then increases, due to the precipitation of buffer salts, during heating (95).

The effect of heat on the vitamins is discussed in a previous section of this chapter.

The Nutritive Value of Milk and Milk Products

As is obvious from the discussion on the nutritive properties of milk constituents, the heat energy value, also called food energy value of calorific value, when expressed in Calories, of milk and milk products depends upon the proportions of fat, protein and carbohydrate present. It depends also upon the digestibility of these constituents. From the discussion of the composition of milk and causes of its variation, it is evident that the calorific value of whole milk varies considerably. Because of this variation and also because the processing of milk usually cannot be sufficiently controlled to eliminate variations in the final products, the food value of different samples of any of the milk products is variable. It is possible, however, by dealing with averages to get some idea of the comparative value of these different food materials.

The composition of milk products depends upon the constituents of milk which are present as well as upon the proportions in which they occur. The constituents of milk which compose a particular milk product will depend upon the composition of the milk from which it was made and upon the proportions of those constituents, contained in that milk, that are retained in the final products. This will depend upon the nature of the treatment given to that milk in the formation of the product. Table "A" is given to show the formation of milk products from raw whole milk. An attempt has been made to indicate the processes that are involved in each case and to show the different products that may result from a separate process or from a series of processes. Where the addition of a non-milk material is essential to the formation of a particular product of milk, the material so added is indicated, such as the addition of salt in the making of market butter and the addition of sugar in the making of ice cream.

Except for losses, which inevitably occur, the constituents contained in the original milk are recovered in the final products. A single product of milk, however, may contain all or a part of only certain of the original milk constituents, usually in a concentrated form, while the remaining constituents are found in the other product or products produced by the same process. This is illustrated in the formation of *makkhan* and *maṭṭhá* when whole milk is churned, or in the formation of *chhená* and

whey when milk is coagulated, at boiling, by the addition of citric acid, citrus fruit juice or sour whey. It may be possible to make any one of several products by a single process, such as the making of *rabaṛí*, *khoá*, condensed or evaporated milk or *khír* by the condensing of whole milk.

The chemical composition of milk and its various products is given in table "B". In the last column the number of Calories of heat energy provided by one pound of each product is indicated. It is evident that the food value of one pound of the different products varies considerably. The calorific value, for example, of a pound of village butter milk or *maṭṭhá* is 173, whereas that of one pound of ghee is 4078. This must not be taken to mean, however, that butter milk is of no value as a food. It does mean, of course, that its food value is very low as compared with ghee. India, however, consumes only an estimated 10,900,000 tons of *maṭṭhá* annually! This milk product makes a considerable contribution to the diet of our rural people in areas where ghee is produced.

As has been explained, the nutritive value of a food product depends not entirely upon its calorific value, since there are characteristics of members of even those food groups which supply heat energy, that is, fats, proteins, and carbohydrates, which make one more valuable than another for food purposes, apart from the heat energy they may supply. Ash does not provide heat energy, although ash or mineral constituents are absolutely essential for proper nutrition.

TABLE "B"

THE COMPOSITION AND CALORIFIC VALUE OF MILK AND MILK PRODUCTS

(FIGURES, EXCEPT CALORIES, SHOW PER CENT)

Products	*Water*	*Fat*	*Protein*	*Lactose*	*Ash*	*Added sugar*	*Calories per lb.*
MILK :—							
Zebu (Red Sindhi) (97) ..	86·56	4·92	3·21	4·58	0·752	..	342
Buffalo (Murrah) (97) ..	83·59	7·16	3·77	4·81	0·765	..	447
MILK PRODUCTS :—							
Cream (zebu)*	..	50·00	1·67	2·39	0·39	..	2112
Cream (buffalo)* ..	..	50·00	2·03	2·60	0·41	..	2122
Butter (salted 2·50%) (46) ..	15·00	81·50	0·60	0·20	0·10	..	3337
Butter (unsalted) (46) ..	15·20	83·50	0·75	0·25	0·15	..	3422
Cheddar Cheese (32) ..	33·89	33·00	27·56	..	3·65	..	1845
Ghee	0·10	99·80	..	..	..	..	4078
Malái (22)	..	27·50	3·20	3·60	0·40	..	1244
Chhená (22)	..	30·00	17·50	2·20	0·30	..	1580
Khoá (whole milk) (22) ..	..	36·00	18·00	30·00	5·00	..	2337
Plain *Khír* (sweetened) (22) ..	..	20·00	10·00	16·00	2·60	24·00	1721
Plain *Khír* (unsweetened) (22)	..	26·00	13·00	20·00	3·30	..	1658
Plain *Khír* (from skim milk) (22)	..	5·00	11·00	18·00	2·70	20·00	1092
Rabaṛí (22)	..	20·00	10·00	17·00	3·00	27·00	1794
Dahí (22)	..	6·50	3·30	4·90	0·70	..	414
Lassí (skim milk) (22) ..	..	0·07	3·40	5·00	0·72	..	155
Malted Milk (Horlick's) (21)	..	8·10	14·80	10·04	3·96	..	780
Whey (44)	..	0·38	0·86	5·00	0·76	..	122
Dry Whole Milk (4) ..	..	26·00	27·20	36·80	6·00	..	2220
Separated or Skim Milk (4)	..	0·15	3·72	4·98	0·80	..	164
Sweetened Condensed Skim Milk (4)	..	1·01	9·14	18·18	2·05	40·88	1277
Dry Skim Milk (4) ..	..	1·00	37·40	49·20	8·40	..	1610
Butter Milk (commercial) (4)	..	0·50	3·30	3·40	0·65	..	142
Maṭṭhá (22)	..	0·50	3·40	5·00	0·72	..	173
Dry Butter Milk (4) ..	..	5·87	38·74	39·91	7·68	..	1665
Condensed Butter Milk (4)	..	1·30	9·90	11·70	2·00	..	444
Evaporated Whole Milk (44)	..	9·10	8·75	12·74	1·94	..	760
Evaporated Skim Milk (44)	..	0·75	8·35	12·50	1·78	..	408
Ice Cream (good average commercial mix) (92) ..	..	12·50		10·00 (protein, lactose and ash together)		16·00	983
Ice Cream (home-made mix without eggs and flour) **	..	13·00	2·47	3·52	0·58	14·00	892

*Calculated, *from the figures given for milk, using* 50 *per cent fat.*

***Calculated, from the figures given for zebu milk, using* 13 *per cent of fat and* 14 *per cent of added sugar (see Appendix VIII).*

TABLE "A"

THE FORMATION OF MILK PRODUCTS

Raw Whole Milk

- —marketed with or without toning → Market milk →
  - → Raw bulk and Raw bottled milk
  - → Pasteurized bulk and Pasteurized bottled milk
  - → Sterilized bottled milk
- —churned with or without ripening —
  - → Village butter or *Makkhan*—heated → Ghee
  - → *Maṭṭhá* or *Chháchh*
- —coagulated with starter →
  - → *Dahí* → *Lassí*
  - → Artificial butter milk and other Fermented milks
  - → Starter
- —coagulated with starter and/or rennet —
  - → Whey →
    - → Lactose
    - —dried → Dried whey
    - → Animal food
  - → Cheese
- —coagulated with citric acid, citrus fruit juice or sour whey—
  - → Whey →
    - → Lactose
    - —dried → Dried whey
    - → Animal food
  - → *Chenná* → *Miṭhái*
- —condensed →
  - → *Rabaṛí*
  - → *Khoá* → *Miṭhái*
  - → Sweetened condensed, Unsweetened condensed and Evaporated whole milk
  - → *Khír*
- —separated—
  - → Cream or *Malái* →
    - → Raw and Pasteurized market cream
    - —frozen with milk and sugar → Ice cream
    - —coagulated → Cream cheese
    - —heated → Ghee
    - —churned with or without ripening —
      - → Butter granules →
        - —worked with or without salt → Market butter
        - —heated → Ghee
      - → Butter milk →
        - —dried → Dried butter milk
        - —condensed → Condensed butter milk
        - → Animal food
  - → Separated or Skim milk →
    - → Human food
    - —condensed → Sweetened and Unsweetened condensed skim milk
    - —dried → Dried skim milk
    - → Animal food
    - —coagulated →
      - —
        - → Cottage cheese
        - → Casein → Paint, Glue, Plastics, Fibre
        - → Whey —
          - → Lactose
          - —dried → Dried whey
          - → Animal food
      - → Skim milk curds or *Dahí* → *Lassí*
- —frozen with or without cream and sugar →
  - → *Kulafí*
  - → Ice Cream
- —dried → Milk powder, Malted milk and Patented milk foods (for infants)

Note:—Hindustani names for indigenous milk products are spelled in this book according to the Roman equivalent, as given in the First Lessons in Hindi by G. J. Dann (1937), published by Jagannath Prasad, Banaras, of one of the possible spellings in the *Deva Nágarí* found in *Bháshá Sabd-Kosh* by *Dr. Rámashankar Shukla* (1939), published by *Rámanáráyan Lál*, Allahabad. There are commonly several different names for a single product, some of which apply to two different products. For this reason, differences of opinion will occur. For example, *lassí* and *maṭṭhá* are used interchangeably in some localities, whereas according to the chart they are so different in their origin as to make this a mistake.

Words which represent products are capitalized; those indicating processes are not. Lines leading to products are pointed with an arrow; those leading to process are not. Brackets indicate products made simultaneously by a single process if the line leading to them is unpointed with an arrow; otherwise they indicate products which can only be made separately. *Kulafí* and ice cream, for example, cannot be made simultaneously by freezing milk, whereas cream and separated milk both result at the same time from separating whole milk. In a series of products in one line, 'and' indicates separate products, 'or' indicates names which are synonyms.

This table was designed with the help of Mr. Adin P. Brooks, M.Sc., Department of Chemistry, Allahabad Agricultural Institute, Allahabad.

CHAPTER V

DAIRY CHEMISTRY

Determination of the Percentage of Fat by the Gerber Method

The dairy industry owes a considerable debt to Dr. N. Gerber of Switzerland and Dr. S. M. Babcock of the United States who invented simple methods of determining the percentage of butter fat in milk and milk products. Dr. Gerber announced his method in 1892 (62), while Dr. Babcock announced his in 1890 (31). Gerber's method is used more commonly in India than that of Babcock.

Whole Milk

The following details show the method of testing for the fat percentage in whole milk (9).

Apparatus Required—Standard Gerber test bottles or butyrometers designed for testing whole milk ; rubber stoppers; 11 ml. milk pipette; 10 ml. acid pipette; 1 ml. alcohol pipette; centrifuge with a working speed of 1100 R. P. M., having a diameter of 18 to 20 inches; a thermometer with a range of 30° to 215°F.; and a water bath which can be held at the desired temperature.

Reagents Required—Sulphuric acid having a density of 1·815g/ml.; and amyl alcohol.

Procedure—Add 10 ml. of sulphuric acid to the test bottle. Mix the milk sample carefully by pouring it back and forth into a second container three times, allow it to stand for three minutes so that gas bubbles may pass off and add 11 ml. to the test bottle containing the acid. Care must be taken to add the milk in such a manner that it flows down the inside of the test bottle and mixes as little as possible with the acid. Add 1 ml. of amyl alcohol taking care not to wet the neck of the test bottle. A dry Gerber rubber stopper is then inserted into the bottle until the wide part of the stopper is inside the neck

of the bottle. Protecting the hands with a cloth, mix the contents of the test bottle by shaking and inverting it until all curd has dissolved. Place the test bottles in the water bath with the stoppers downward. The temperature of the water bath should be 154°F. The bottles may be held here until a sufficient number of them are ready to just fill the centrifuge. They are then placed in the centrifuge. All centrifuge cups must be filled or, if the number of test bottles does not permit, opposite cups should be filled so that the load on the revolving disc is symmetrical. A test bottle filled with water and stoppered may be required to give this symmetry without which the machine will be unbalanced. If this precaution is not taken test bottles are liable to break and undue wear on the machine will greatly reduce its useful life. The bottles are then rotated in the centrifuge for 4 to 5 minutes at 1100 R. P. M. The test bottles are again placed in the water bath at 154°F. for 2 to 3 minutes when they are read and checked. Holding the test bottle in a vertical position with the calibrated portion at the level of the eyes, read the bottom of the two menisci, that is, the two surfaces of the fat column. The difference between these two readings gives the percentage of fat in the milk. This is checked by again making the reading after the test bottles have been replaced in the water bath for 2 or 3 minutes.

Skim Milk, Separated Milk and Butter Milk

The following details show the method of testing for the fat percentage in skim milk, separated milk and butter milk (9).

Apparatus Required—Standard Gerber test bottles designed for testing skim milk are used instead of those required for whole milk, otherwise the apparatus for testing these milk products is the same as is listed above.

Reagents Required—The same reagents are required as for whole milk.

Procedure—Add 10 ml. of sulphuric acid, 11 ml. of the sample and 1 ml. of amyl alcohol as in the case of whole milk. The procedure subsequently is the same as for whole milk up to and including the first centrifuging. The test bottles are then placed in the water bath at 154°F., stoppers down, for 1 to 2 minutes and again centrifuged for 4 to 5 minutes at the usual speed. They are again placed in the water bath for 2 to 3

minutes and read. A check reading is made after they are placed in the water bath a third time for 2 to 3 minutes. The readings so obtained must be corrected as follows:

Percentage read on the test bottle	Correction
Less than 0·10 per cent	Adult 0·05 per cent
0·10 per cent to 0·25 per cent	Add 0·02 per cent
More than 0·25 per cent	No correction required

Cream

The following details show the method of testing for the fat percentage in cream (9).

Apparatus Required—The apparatus required for whole milk, except for the test bottle and the 11 ml. pipette, is supplemented by certain additional items for testing cream. The test bottles are standard Gerber cream test bottles. Other items include a balance for weighing to 0·001 or 0·005g.; a stand to support the test bottle on the balance or a stoppered weighing funnel, and a wash bottle containing warm distilled water at a temperature of 86° to 104°F.

Reagents Required—The same reagents are required as for whole milk.

Procedure—Mix the sample thoroughly, though cautiously, to avoid causing frothing. If the sample is very thick it should be warmed to between 100° and 122°F. to facilitate mixing. Weigh 5g. of cream into the testing bottle or into the stoppered weighing funnel. In the latter case the cream must then be transferred to the test bottle by draining and washing the contents of the weighing funnel into it. Add about 6 ml. of warm distilled water from the wash bottle. Add 10 ml. of sulphuric acid and 1 ml. of amyl alcohol. Additional warm distilled water may now be added to bring the level of the contents of the test bottle to about 5 mm. below the neck of the bottle. Stopper as suggested under whole milk and mix the contents, by inverting the test bottle several times carefully, until the curd is all dissolved. Place in the water bath at 154°F. with the stoppers down until the tests are ready to centrifuge. Centrifuge at the speed stated for whole milk about 4 to 5 minutes and place in the water bath again for 2 to 3 minutes. If the dividing line between the fat and the acid is not clear the bottles may be centri-

fuged and placed in the water bath repeatedly as indicated until this dividing line is clear. Both the first and the check readings are then made as suggested for whole milk, placing the bottles in the water bath for 2 to 5 minutes between the two.

Determination of the Specific Gravity of Milk

The specific gravity of a substance is the ratio of its mass at a known temperature to the mass of an equal volume of water at 4°C. or other specified temperature (32). The unit of mass employed is the gram; that of volume, the millilitre. The density of most materials varies with the temperature. The density of water is greatest at 4°C.

A hydrometer is an instrument for measuring specific gravity of liquids. It is designed to float upright. The lower portion is of a large diameter to increase its displacement when submerged. The upper part or stem is of a very small diameter and contains a scale from which readings may be made at the level of the liquid while the hydrometer floats freely. The instrument may or may not be fitted with a thermometer with which to check the temperature at the time the reading is made.

An object submerged in a liquid is buoyed up by a force equal to the weight of the liquid displaced by it. A floating object, therefore, floats at a level at which the weight of the liquid it displaces is equal to the weight of the object. Since the hydrometer is of a fixed size, the volume it displaces at different temperatures is practically the same. The weight of a fixed volume, that is the density, of a liquid, however, varies with the temperature. Consequently, as the temperature changes, the weight of the volume displaced by the hydrometer will vary, so that the height to which the instrument will float will depend upon the temperature, among other things, of the liquid in which it is submerged. The density of a solution will depend upon its concentration, and upon the nature of both the solvent and the solute, as well as upon its temperature.

The Specific Gravity Test

The lactometer is a hydrometer that is especially designed for use in milk. According to the British Standard Specifica-

tions (10), the calibrations of the milk hydrometer for use in "normal milks" should cover a density range of 1·025 to 1·035 g./ml. at 20°C. (68°F.), while those for milk hydrometers for use in "milks of low density" should cover a density range of 1·015 to 1·025 g./ml. at 20°C. Other lactometers may be calibrated to read correctly at 15·6°C. (60°F.) or some other temperature, over a range of 15 to 45, corresponding to a specific gravity range of 1·015 to 1·045 (62). The calibrations in most cases are marked in such a manner that the specific gravity must be calculated from the corrected reading, according to the following formula in which R is the lactometer reading after correcting for temperature.

$$\frac{R}{1000}+1=\text{Specific Gravity}$$

The readings must be corrected for temperature, except when the temperature of the sample is exactly that at which the lactometer is calibrated to read correctly.

Apparatus Required—A standard lactometer, a standard thermometer and a cylinder in which the sample may be placed for making the readings.

Procedure—Adjust the temperature of the sample as nearly as possible to that for which the lactometer is calibrated. Place the sample in the cylinder, filling it to a point at which the immersion of the lactometer will bring the level of the sample up to the top edge of the cylinder. Insert the lactometer carefully, making sure it floats freely. Read the lactometer scale at the surface of the sample; take the temperature of the sample; and record both readings. For lactometers calibrated to read correctly at 15·5°C. (60°F.) the reading is corrected for temperature according to the following plan (31): between 10°C. (50°F.) and 21·1°C. (70°F.) add 0·1 to the lactometer reading for each degree above 60°F. and subtract 0·1 from the lactometer reading for each degree below 60°F.

The milk tends to wet the lactometer stem in such a manner that it appears to be drawn up the outside of the stem where it extends above the milk. The reading must not be made at the highest point on the stem to which the milk is drawn, but at the true level of the milk.

Specific Gravity as an Indication of Adulteration

The specific gravity of normal or genuine zebu whole milk varies from 1·019 to 1·036, while the variation for buffalo whole milk is from 1·018 to 1·038. The majority of the samples show values between 1·028 and 1·032, with a mean of 1·0306, for zebu milk and between 1·029 and 1·034, with a mean of 1·0314, for buffalo milk (97). From these data it is obvious that the specific gravity cannot be relied upon as conclusive evidence of the adulteration of milk by the addition of water, at least so far as a large proportion of the milk available is concerned. A sample of zebu milk, for example, with a specific gravity of 1·032 may be adulterated approximately 12½ per cent with added water before the specific gravity drops to 1·028.

According to the formula given above and the variations in the lactometer readings which result from differences between the temperature at which the readings are made and that at which the instrument is calibrated to read correctly, it is easy to see that an error of the order of 0·010 may arise from reading the lactometer at 70°F. and failing to correct that reading for temperature. Small household lactometers, therefore, are absolutely unreliable in most cases, as readings are made at any temperature without correction and most people, certainly the average consumer of milk, have no knowledge of the true character of milk. The specific gravity test may be used by the chemist or public analyst, however, to reveal suspicious samples. Adulteration can then be confirmed by supplementing the information provided by this test with that obtained by additional tests for other characters of milk, such as the butter fat content and the freezing point.

Determination of the Total Solids of Milk

The procedure for determining the total solids of milk is as follows (5). Spread 15 to 20 g. of pure dry sand in a flat-bottomed aluminium dish; heat the dish and sand in a drying oven at 100°C., cool in a desiccator and weigh. Add 1·5 to 3·0 ml. of milk to this dish, weigh quickly, evaporate over a steam bath for 30 minutes and dry in the drying oven at 100°C., preferably in a vacuum, to constant weight. Cool the dish and its contents in a desiccator and reweigh quickly to avoid

the absorption of moisture. The weight of the sample residue, divided by the weight of the sample and multiplied by 100 gives the per cent of total solids in the sample.

Determination of the Titratable Acidity of Milk and Milk Products

There are two types of acidity of milk. One is natural acidity, the other developed acidity. The natural acidity of milk is not due to lactic acid, the acid produced by bacteria which ferment lactose; it is due to the action of certain salts of milk, principally phosphates and citrates; to carbon dioxide; and to the alkali-binding properties of casein and albumen (31, 62 and 93). The developed acidity results from the bacterial fermentation of lactose with the production of lactic acid.

The natural acidity of fresh milk varies somewhat, but is usually, when calculated as lactic acid, equivalent to between 0·12 and 0·18 per cent of the milk. Any acidity in excess of that naturally present in the milk as it is drawn from the udder is developed and may be taken as an indication of the bacterial condition of the milk. A sour flavour becomes noticeable at an acidity of between 0·20 and 0·25 per cent, depending upon the sensitivity of one's sense of taste. Coagulation will normally take place as the acidity nears 0·65 per cent (32).

The Acidity Test

The titratable acidity of milk and milk products is determined by titration. The details of the test are as follows.

Apparatus Required—A porcelain cup ; a glass stirring rod ; 9·0 and 17·6 ml. pipettes; and a burette equipped with a pinch cock.

Reagents Required—A solution of N/10 sodium hydroxide (NaOH) and a one per cent alcoholic solution of phenolphthalein.

Procedure—The following procedure may, with the modifications mentioned, be used for whole milk, skim milk, separated milk, butter milk, whey, *dahí* and cream. Fill the burette with N/10 NaOH. Prepare the sample by thorough mixing; air bubbles should be allowed to pass off before the desired quantity for the test is measured. *Dahí* will have to be broken up very finely to make contact of the NaOH with all portions of the curd possible; the finer the curd particles the

more accurate will be the results. Place the required quantity of the sample in the porcelain cup. The quantity is 18 grams, although 9 grams of cream are usually used. The 17·6 ml. pipette will, for all practical purposes, deliver 18 grams of each of the products named above except cream; the 9 ml. pipette will deliver approximately 9 grams of cream. The cream pipette is usually rinsed with one pipette-full of distilled water, but this is not done when testing the other products. Such rinsing makes it necessary to use a different factor for calculating the acidity from the ml. of NaOH used in the titration than that required when the pipette is not rinsed. This is discussed below. The cream sample should be weighed for more accurate results.

Add 2 to 3 drops of the indicator to the sample in the cup, note the reading of the burette at the bottom of the meniscus of the NaOH and slowly titrate. When the end-point is reached a slight pink colour will appear which remains just one minute. It disappears because the absorption of carbondioxide from the air increases the acid content of the sample. The burette is again read at the bottom of the meniscus of the NaOH. The first reading is subtracted from the second to give the ml. of N/10 NaOH required to titrate the sample to the desired end-point. The acidity is then calculated.

Calculations—The titratable acidity of milk or milk products is usually expressed as lactic acid in terms of percentage of the material concerned. Although the natural acidity is not due to this acid, it is the most common acid found in milk. Since one equivalent weight of lactic acid will just neutralize one equivalent weight of NaOH, there is a quantitative relationship between the amount of NaOH required to neutralize the acid contained in a given quantity of milk and the acid content of that milk. The designation of the NaOH solution as N/10 indicates that it is one-tenth normal or that it contains exactly one-tenth of one equivalent weight of NaOH in one litre of solution. The equivalent weight of NaOH is 40·01 grams; that of lactic acid is 90·06 grams. Hence, 40·01 grams of NaOH will neutralize 90·06 grams of lactic acid; 4·001 grams of NaOH will neutralize 9·006 grams of lactic acid; or 0·004 grams of NaOH, the amount contained in 1 ml. of N/10 solution of this material, will neutralize 0·009 grams of lactic acid. The per cent of lactic

acid, therefore, in a sample, as determined by this method, is:

$$\text{Per cent lactic acid} = \frac{\text{ml.N/10 NaOH} \times 0 \cdot 009}{\text{gram of sample}} \times 100.$$

Since the sample, except for cream, weighs 18 grams, the formula becomes:

Per cent lactic acid = ml. N/10 NaOH $\times$ 0·05

In the case of cream, however, where the sample is only 9 grams, the formula becomes:

Per cent lactic acid = ml. N/10 NaOH $\times$ 0·10

Determination of the Freezing Point of Milk

A brief discussion of the osmotic pressure of milk is given in Chapter III. The freezing point determination is a test for the concentration of molecules and ions in true solution and is, in a sense therefore, a test for the osmotic pressure of milk. The freezing point is that temperature at which a substance may appear as a solid and as a liquid at the same time, that is, at which these two states of the substance are in equilibrium. The more dissolved substances there are in a unit of the solvent the more difficult it is to cause crystals to form, hence the lower the freezing point. The addition of water to milk dilutes the solution, that is, it reduces the concentration of the solute per unit of solvent; the result of this action is a lowering of the osmotic pressure and a lowering of the freezing point depression. The freezing point depression in the case of milk is the degrees below zero Centigrade at which freezing takes place. The freezing point depression of milk of the zebu cows (see Chapter IV) averages 0·5455, while that of the buffalo averages 0·5426. These values are equivalent to freezing points of —0·5455°C. for zebu milk and —0·5426°C. for buffalo milk. The most constant physical property of milk is the freezing point, according to Davies (21), who adds that the value of the freezing point determination as a means of differentiating genuine poor milk from milk to which water has been added cannot be overestimated. This author, in another reference (22), also states that added water can be detected with almost complete certainty by means of the freezing point test. This, it may be concluded, is the only reliable test for the detection of added water in milk. The

lowering of the freezing point depression is directly proportional to the amount of added water.

The test is reliable for fresh milk only, however, as acid development, resulting in the conversion of a certain amount of lactose into lactic acid, increases the ions in solution and thereby causes an increase in the freezing point depression, that is, a decrease in the freezing point. Fresh milk may be taken to mean milk with a titratable acidity of 0·18 per cent or less.

Apparatus Required—A Hortvet cryoscope which is constructed somewhat as follows is required. The neck of a Dewar flask of one litre capacity is closed with a large cork stopper through which passes a medium thin-walled metal tube containing the glass freezing tube; a metal inlet tube the lower end of which is a perforated loop near the bottom of the flask; a metal T-shaped tube through which to admit liquid ether and through which the vaporized ether may escape; a control thermometer; and a guage tube. The freezing tube, which fits closely into the metal tube in which it is held, is closed with a rubber stopper through which passes a standard thermometer; a stirring device, fitted through a short section of thin-walled metal tubing, the lower end of which is a loop encircling the standard thermometer; and a freezing-starter attachment.

At one side of the cryoscope is an air-drying attachment consisting of a large test tube closed with a rubber stopper fitted with a Folin absorption bulb, extending nearly to the bottom of the tube; and a short section of glass tubing which is connected with the vaporizing tube that enters the cryoscope. On the opposite side of the cryoscope is a drain tube for carrying vapours away from the operator. A pressure and suction pump provides dry air, which is forced through the apparatus at the desired rate, and suction, which removes the mixed vapours through the drain tube.

The standard thermometer is graduated from minus 2·00° to plus 1·00°C. with graduations at 0·01°C. intervals with easy estimation to 0·001° to 0·002°C. possible.

Procedure—A small amount of sulphuric acid, sufficient to cover the Folin bulb, is put into the drying tube; sufficient alcohol is put into the metal tube holding the freezing tube to fill the space between the two; a quantity of ether, about 400 ml., is put into the Dewar flask; the apparatus is completely assembled.

The pump is then started and the air passed through the apparatus at a moderate rate until the temperature in the flask is reduced, due to the evaporation of the ether, to about minus 3°C. as shown by the control thermometer. Adjust the level of ether in the flask to replace losses and place sufficient quantity of the material to be tested, 30 or 35 ml., in the freezing tube to cover the bulb of the standard thermometer. Keep the stirring device moving up and down about once each one to two seconds as the air passes through the apparatus. Continue this until the sample is super-cooled to 1·0° to 1·2°C. If freezing does not begin at this time a small crystal of ice may be introduced by the freezing-starter attachment to start the freezing. The temperature of the sample will then increase a little, stopping at the freezing point of the material under test. The stirrer should then be operated slowly only three or four times and the standard thermometer tapped with a cork hammer. The reading is then made on the standard thermometer to the nearest 0·001°C. and recorded.

The zero point of the standard thermometer must be checked each day by checking the freezing point of well boiled distilled water on the basis of which a correction factor is applied to the reading obtained when milk is being tested. The sample of milk is cooled to about 10°C. before it is placed in the freezing tube for testing.

Determination of the Amount of Added Water

The amount of added water in milk may be determined by the freezing point test by comparing the freezing point of a given sample with the normal freezing point of genuine milk of the same type. The following formula is used for this purpose:

$$W = \frac{100\,(T - T^1)}{T}$$

where W is the percentage of added water, T is the average freezing point of normal milk and T^1 is the true (corrected) freezing point of a given sample. A tolerance of 3 per cent on the results for added water is allowed because of variations found in market milks of genuine character; that is adulteration by the addition of over 3 per cent added water can be detected by this test.

The Chemistry of Chlorine Sterilization

Chlorine solutions, referred to in Chapter VIII, may be prepared by the use of chlorinated lime and washing soda, a hypochlorite, chlorine gas or by the electrolysis of common salt. The germicidal strength of such solutions depends principally upon the availability of the nascent or atomic oxygen they contain, although it is understood that molecular chlorine plays a part. The strength of such solution is measured in terms of the chloine they contain which is available. It is expressed as parts of available chlorine per million parts of solution, or p.p.m. available chlorine.

The following chemical formulæ represent the reactions which take place in the preparation of chlorine solutions.

Chlorinated Lime plus Washing Soda

Bleaching powder or chlorinated lime ($CaOCl_2$) and sodium carbonate or washing soda (Na_2CO_3), in the presence of water, combine to give sodium hypochlorite ($NaOCl$), calcium chloride ($CaCl_2$) and calcium carbonate ($CaCO_3$).

1. $2CaOCl_2 + Na_2CO_3 \rightarrow 2NaOCl + CaCl_2 + CaCO_3$.

The sodium hypochlorite then breaks down in water to give sodium hydroxide ($NaOH$) and hypochlorous acid ($HOCl$).

2. $NaOCl + H_2O \rightarrow NaOH + HOCl$.

Hypochlorous acid is unstable in water, breaking down into hydrochloric acid (HCl) and nascent oxygen (O). Molecular oxygen (O_2)is not produced ; if it were, however, it would pass off into the atmosphere as a gas. The nascent oxygen does not pass off in this manner as it is such an extremely active substance that it reacts readily with any organic material, including bacterial cells, milk solids, bits of feed material, hairs and wood, as soon as it becomes available as a result of the reactions shown.

3. $HOCl \rightleftarrows HCl + O$.

Hydrochloric acid reacts with calcium hypochlorite to give calcium chloride, water and molecular chlorine (Cl_2). Chlorine in the molecular form is a gas, but since it is soluble in water most of it remains in the solution, although it will gradually pass off into the atmosphere unless the solution containing it is kept in the dark in a stoppered container. The container must

be made of glass or glazed earthenware. Light effects the dissipation of chlorine in such solutions. Being present, the chlorine reacts to a certain extent with organic material to which it finds access. This reaction, like that with atomic oxygen, causes death to bacterial cells if the concentrations are great enough.

4. $2HCl + CaOCl_2 \rightarrow CaCl_2 + H_2O + Cl_2$.

Preparation of Chlorinated Lime—Bleaching powder or chlorinated lime may be prepared by mixing chlorine gas with ordinary slaked lime ($Ca(OH)_2$), thus:

5. $Ca(OH)_2 + Cl_2 \rightarrow CaCl(OCl)$ or $CaOCl_2 + H_2O$.

The chlorinated lime may then be used as shown in formulæ 1 to 4 in the preparation and use of chlorine sterilizing solutions.

Preparation of Sodium Hypochlorite—This material may be prepared in one of two different ways. When chlorine gas is mixed with a solution of sodium hydroxide, sodium hypochlorite is produced along with sodium chloride and water, as follows:

6. $2NaOH + Cl_2 \rightarrow NaOCl + NaCl + H_2O$.

Secondly, an electrolytic method may be employed. The electrolysis of a solution of sodium chloride in water gives hydrogen (H_2) at the cathode and chlorine (Cl_2) at the anode, leaving sodium hydroxide in the solution. If these substances are allowed to mix during the reaction, sodium hypochlorite is produced. This process must be carried out at low temperatures, however, for if the solution through which the current is being passed is warm, the hypochlorite will decompose to form sodium chlorate. The following formula, according to Deming (25), shows the reaction involved:

7. $2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$.

The sodium hydroxide and the chlorine then combine in the manner shown by formula 6. The sodium hypochlorite produced by either of the methods is then used, as shown by formulæ 2, 3 and 4, in preparing solutions of the required strength.

Preparation of Hypochlorous Acid—Chlorine gas mixed with water produces hydrochloric and hypochlorous acids. This reaction is reversible as in the breakdown of the hypochlorous acid so produced into hydrochloric acid and nascent oxygen, as shown in formula 3. This reaction is as follows:

8. $H_2O + Cl_2 \rightleftarrows HOCl + HCl \rightleftarrows 2HCl + O$.

Preparation of Chlorine Gas—Formula 7 shows the preparation of chlorine gas. Instead of mixing hydrogen, chlorine

and sodium hydroxide which are formed, as is done in the preparation of sodium hypochlorite by this method, the hydrogen and chlorine are drawn off separately, giving pure gases of both types. They are usually compressed into cylinders in which they are marketed.

Heat Coagulation Point of Milk and Factors Affecting It

The heat coagulation point of milk refers to the temperature-time treatment which coagulates the proteins of milk. The coagulation of milk and the methods by which it is normally brought about in the processing of milk are discussed in Chapter VIII. Numerous factors contribute to the stability of the proteins of milk when exposed to heat. Some of these are discussed below. Much of the material for this discussion is taken from Hunziker (45). The importance of this physical character of milk has to do with the ease with which coagulation takes place in fresh and ordinary market milk on heating, the ability of the proteins to withstand pasteurization, homogenization and holding in storage as well as the firmness of the curd that is produced under conditions which bring about coagulation, such as in the making of *dahí* and cheese.

The Heat Coagulation of Fresh Milk

The temperature-time exposure at which fresh milk will coagulate depends upon the composition of the milk. Reference to Chapter IV will show the many factors contributing to variations in the chemical composition of fresh milk. Under the section dealing with the stage of lactation it will be noted that, so far as the chemical composition of the milk is concerned, the lactation may be divided into three periods.

Colostrum differs very greatly from what is usually known as normal milk, principally in a greater albumin, globulin and ash content. The fact that albumin and globulin readily coagulate on heating is indicated by the coagulation or colostrum on heating. The higher content of these proteins in colostrum accounts for this. Davies (21) suggests that toward the end of the colostral period the colostrum may have a lower heat stability, apart from the influence of the proteins.

Milk, as produced during the normal lactation period, varies considerably in chemical composition, although its heat sta-

bility is fairly constant when fresh, provided the animal is in good health, the udder is healthy and feeding conditions are regular. The casein of fresh milk coagulates at temperatures between 270° and 280°F. under pressure. At pasteurization temperature the ability of the casein to coagulate with rennet is affected only slightly, if at all. Albumin is partially coagulated in normal milk by pasteurization. Rennet does not affect this protein. Diseases, particularly mastitis, cause variations in the composition of milk which alter, sometimes appreciably, the heat coagulation point of the milk. In the case of mastitis, the albumin, globulin and chlorine increase, while the lactose and most other ash constituents decrease. Such milk is noticeably unstable to heat, so much so in fact that the presence of a small amount of mastitis milk in a quantity of herd milk may make the whole quantity unfit for condensing or drying because it coagulates at the temperatures employed in the manufacture of the products.

Miik produced during the extended lactation shows a gradual increase in the Ca: P ratio and an increase in chlorine content. Here again, the heat stability of the milk is affected so that it coagulates more readily on heating.

The Effect of Acidity

Natural acidity does not lower the heat coagulation point of the milk. As the acidity increases, the heat coagulation point of milk decreases. At a titratable acidity of about 0·51 to 0·66 per cent, normal fresh milk will coagulate at ordinary temperatures. As the lactose is converted into lactic acid, the citric acid tends to be destroyed. This causes an excess of available calcium which disturbs the calcium-casein balance. This is one of the most important factors in bringing about changes in the heat coagulation point of milk. The excess of calcium is accompanied by a change of primary phosphate into secondary phosphate in which form the phosphate has less effect on counteracting the calcium and magnesium salts. This accounts for the occasional coagulation of market milk on heating. The acidity in such cases is insufficient to cause coagulation at ordinary air temperature but sufficient to cause it at slightly higher temperatures.

Acid develops in milk by the action of micro-organisms. Certain of these produce only acid while growing in milk; others,

however, which may or may not produce acid, produce other products which may bring about changes in the milk that affect its heat coagulation point. Those which produce coagulating enzymes, that is, the sweet curdlers for example, may cause coagulation of milk with no change in the acidity, or occasionally with a decrease of acidity.

The Effect of Forewarming

Forewarming or preheating the milk refers to the process of heating the milk to high temperatures for a period of time to bring about an increased heat stability during subsequent treatment. This process is a regular practice in the making of much of the condensed or dried milk that is manufactured. In forewarming milk it is heated up to as high a temperature as 230°F. and held for 5 to 10 minutes. It is thought that this treatment precipitates some of the soluble calcium and thereby stabilizes the milk casein to heat. At the same time the albumin is precipitated, which seems to be a contributing factor to the effect of this process on the heat stability of the milk involved.

The Effect of Salts

This point has been partially discussed in a section above. The effect of the calcium and magnesium salts is opposed to that of the citrates and phosphates. An excess of either group, however, will cause more rapid coagulation. The greatest stability comes when these two groups of salts are present in the proper proportion. As additional calcium becomes available, due to the effect of acid as it develops, coagulation can be avoided by the addition of citrates or phosphates. Preheating the milk reduces the available calcium by precipitating part of the soluble calcium as calcium phosphate. Pasteurization has this same effect, although not to so great an extent. The addition of calcium chloride to milk which has been pasteurized or otherwise preheated facilitates coagulation with rennet by replacing the soluble calcium that was removed by the heat treatment.

The Effect of Concentration

Hunziker states that as the concentration of evaporated milk increases the heat coagulation point decreases. It is

presumed that this holds likewise for other types of concentrated milk products, such as *khoá*, *khír* and *rabaṛí*. The importance of the best milk available for the manufacture of these products, therefore, becomes clearer when this fact, together with others mentioned elsewhere, is considered.

Crystallization

The practical dairyman will notice the formation of crystals under certain conditions in several of his products. He will notice that crystals usually form when certain materials are cooled. The factors involved are somewhat similar, although not identical, to those which cause the condensation of moisture on the outside of a drinking glass when filled with cold water or sherbet, during the monsoon season. The amount of water contained in a volume of air at the temperatures common during that season is greater than the amount that same air can hold at lower temperatures. The moist warm air is cooled as it comes into contact with the cold surface of the glass. At the lower temperature it is unable to hold all the water it contains so that some condenses out.

In the case of the formation of crystals in solutions on cooling, the amount of material that can be held in solution by a given volume of solvent at a given temperature is greater than that at a lower temperature. As the temperature of the solution decreases it may eventually reach a point at which some of the solute will crystallize out. This is what occurs in the formation of crystals of lactose or sucrose in *khoá* and condensed milk on cooling.

At that temperature at which a material turns from a liquid into a solid, as the latent heat of fusion is removed, crystallization likewise occurs. This happens in the formation of grains in ghee during cooling or in the formation of ice in the freezing of water, or the making of ice cream and *kulafí*.

Crystals form around nuclei or bits of solid material. In the absence of nuclei, crystallization may take place but supercooling is required. This means that the material must be cooled to a temperature somewhat below that at which freezing or solidification normally occurs. As soon as crystallization begins, however, the temperature returns to the freezing temperature characteristic of the solution involved. This

phenomenon is observed in making the freezing point test of milk by use of the Hortvet cryoscope.

At any temperature the quantity of material that will remain in solution in a given quantity of solvent is fixed. Only that quantity of solute present in excess of this amount will crystallize out. The quantity of solvent is also fixed so that were it to freeze, as it does in the cooling of ghee and the making of ice, ice cream or *kulafi*, crystal formation is again quantitative. This fact makes it obvious that the smaller the number of crystals, the larger they will be; and the greater the number, the smaller they will be. Were one tree to be split into match sticks, the total quantity of wood would be exactly the same in one form as in another, but the number of match sticks would be very much greater than the one tree, and they would be much smaller. Whatever will enable the formation of large numbers of crystals, therefore, will give small or fine crystals; whatever brings about the formation of a small number of crystals will give large crystals. The speed of cooling at that temperature at which crystallization occurs determines the number, and therefore the size, of the crystals. Rapid freezing of the mix used for making ice cream or *kulafi* gives small crystals; rapid cooling of ghee gives small crystals or grains; and rapid cooling of *khoá* or condensed milk gives small crystals. In as much as good grains in ghee implies large crystals, ghee should be cooled slowly to give the desired grain or texture. The more suddenly ice cream or *kulafi* is frozen or *khoá* and condensed milk are cooled, the finer the texture these products will have. Condensed milk may be seeded by sprinkling a quantity of finely ground lactose into it during cooling to increase the number of nuclei for crystal formation in order that each one will be small. This gives a finer texture to the product.

Water expands upon freezing, and all crystals tend to grow in size during formation, particularly when produced slowly. These facts are taken into account in the application of the process of quick freezing in the preservation of fruits and vegetables which has become so common in recent years. Sudden freezing produces a very great number of small crystals within each plant cell making up the fruits or vegetables. This tends to preserve the cell walls which might be ruptured by large crystals. Furthermore, slow freezing of a solution tends

to bring about the separation of the solute from the solvent as the latter freezes, leaving the former behind in the remaining unfrozen solvent. This separation of materials, were it to occur, would bring about a destruction of the physical nature of the plant material involved. Upon thawing the solute and solvent which were so separated would not return to their original physical relationship or form. Spoilage on thawing would be more rapid and the texture and quality of the food would be adversely affected. Freezing for such purposes, it will be seen, must be brought about suddenly for best results.

Neutralization of Cream

The principles involved in the neutralization of cream for butter making are discussed in Chapter IX. The following soda and lime compounds are commonly used for this purpose.

Soda compounds		Lime compounds	
Sodium bicarbonate	$NaHCO_3$	Calcium oxide	CaO
Sodium carbonate	Na_2CO_3	Calcium hydroxide	$Ca(OH)_2$
Sodium hydroxide	$NaOH$	Magnesium oxide	MgO
		Magnesium hydroxide	$Mg(OH)_2$
		Magnesium carbonate	$MgCO_3$

Of these $Ca(OH)_2$ may be used to illustrate the chemistry of neutralizing cream.

As is discussed elsewhere in this chapter, under the determination of the titratable acidity of milk, one equivalent weight of an acid will just neutralize one equivalent weight of an alkali. Lactic acid and lime react in the following manner (31):

$$2C_3H_6O_3 \text{ (lactic acid)} + Ca(OH)_2 \text{ (lime)} \rightarrow Ca(C_3H_5O_3)_2 \text{ (calcium lactate)} + 2H_2O \text{ (water)}.$$

The equivalent weight of lactic acid is 90·06 grams, that of lime is 37·05; hence 90 grams of lactic acid are neutralized by 37 grams of lime. In the same way 90 pounds (0·90 pounds) of lactic acid are neutralized by 37 pounds (0·37 pounds) of lime.

The pounds of lactic acid which must be neutralized is determined by multiplying the difference between the initial acidity of the cream and the desired acidity of the cream by the pounds of cream. If, for example, 370 pounds of cream with an acidity of 0·69 per cent were to be neutralized to 0·20 per cent acidity, the pounds of lactic acid to be neutralized would be 0·69 per

cent minus 0·20 per cent multiplied by 370 pounds, or 1·81 pounds. Using the relationship between lactic acid and lime stated above, we have 90 : 37 : : 1·81 : x. Calculation shows that x equals 0·744 pounds, that is, of lime, required. According to Hunziker (47), lime is attracted by the casein of milk or cream, whereas soda neutralizes the serum first. A certain portion of the added lime neutralizer thereby becomes bound to the casein and is not available for neutralizing the acidity of the cream. For this reason, the amount of lime required, as determined by the calculations just given, must be increased by about 20 per cent to give the desired results. Hence the amount of lime neutralizer required in the example given is 0·744 pounds plus 20 per cent or 0·893 pounds. On the other hand, the amount of soda determined by the above method will give the desired results and need not be increased.

Lime neutralizers do not dissolve readily in water, but they should be thoroughly mixed with water before they are added to the cream. The amount of water should be about five pounds for each pound of lime. The mixture should be uniform, homogeneous and free of lumps. Soda neutralizers should be dissolved in water, in about the same proportions, before being used. A stock solution of lime may be prepared to assure more complete mixing of the lime and water and to eliminate the necessity of making up such a solution for each batch of cream. Although the strength of such stock solutions may vary, it is usually 20 per cent. In any case it must be accurately known. A 20 per cent lime solution would contain 0·50 pounds of lime in one Imperial pint. In the example above, 0·893 pounds divided by 0·50 pounds or 1·786 units, that is pints, of such a solution would be required to neutralize the acidity of 370 pounds of cream from 0·69 per cent to 0·20 per cent.

In order to show the amount of lime required to neutralize one pound of lactic acid, the problem in proportion used above may be employed in the following manner: 90 : 37 : : 1 : x. On calculating we find that x equals 0·411 which is theoretically the pounds of lime required to neutralize one pound of lactic acid. Allowing for the additional 20 per cent required, as indicated above, 0·493 pounds of lime will neutralize the equivalent of one pound of lactic acid in

cream. Since one pint of the stock solution contains 0·50 pounds of lime, 0·50 pounds divided by 0·493 pounds, or 0·986 pints will neutralize the equivalent of one pound of lactic acid in cream. The pounds of acid plus 20 per cent, or the pounds of acidity to be neutralized multiplied by 0·986 pints then gives the pints of neutralizer solution required, hence 1·81 pounds times 0·986 equals 1·785 pints.

Chemical Analysis of Butter

Details as to the procedure to follow in making certain determinations of the chemical composition of butter are given by the British Standards Institute (11). For the sake of clarity and to avoid the possibility of leaving out certain points which is almost inevitable in a summary of such material, certain of these standards are given verbatim below.

Preparation of Sample for Analysis

Warm the sample, with the lid of its airtight container screwed down tightly, in an oven, with frequent vigorous shaking, until at the lowest possible temperature a homogeneous fluid emulsion free from unmelted pieces is obtained. When the condition of uniform emulsion is reached, cool with constant vigorous shakings until the consistency is pasty. Weigh portions for analysis at once, keeping, the sample in a homogeneous condition between weighings by shaking. If the sample has been allowed to stand for any length of time in the pasty condition, it must be re-emulsified before further sampling for analysis.

Preparation of the fat for analysis—Heat a portion of the emulsified butter in a beaker until the fat separates from the water and curd. To facilitate separation and filtration, it is advisable that the temperature should not be above 50°C. Filter the fat layer through a dry paper into a dry vessel at a temperature above the solidifying point of the fat. If necessary, re-filter the filtrate under the same conditions until it is clear and free from water. Liquefy the fat completely before taking samples for analysis. Exposure of the warm fat to the air should be as short as possible.

Determination of Moisture

Evaporating Dish—This may be made of platinum, aluminium, nickel, or porcelain, flat-bottomed, about 3 inches in diameter, and not more than 1 inch in depth and provided with a spout. Each dish should be supplied with a glass stirring rod with widened flat end, and should be cleaned, dried in a steam oven, and cooled in a desiccator before use.

Method—Mix the pasty mass of butter with a spoon, weigh accurately from 5 to 6 g. into an evaporating dish, and heat on a boiling water bath or steam bath, with a glass or porcelain ring under the dish to prevent contact between metal of bath and dish, and with frequent stirring until the water has evaporated and the curd is dry. Wipe off the external water, and transfer the dish to a steam oven or electric oven at 98°C. to 100°C.; heat for 30 minutes. Cool in a desiccator and weigh. Repeat heating in the oven, cooling and weighing until the loss in weight between successive weighings does not exceed 1 mg.

First Alternative Method—Heat the dish, with a weighed quantity, about 5 g., of butter, on a hot plate, adjusted so that the temperature of the butter shall reach a temperature not higher than 105°C., for 20 minutes, with frequent stirring. Cool in a desiccator and weigh. Repeat heating and cooling until the weight is constant. Charring of the curd indicates decomposition by overheating and must be avoided.

Second Alternative Method—Dry a dish containing a rod and 5 g. of clean silver sand. Cool and weigh. Add 2-3 g. of butter, weigh accurately, and heat. Mix the melted butter with the sand, and heat in an oven with occasional stirring at a temperature of 100°C. to 105°C. until the weight is constant.

Determination of Curd and Salt

Dry a folded filter paper, 9 cm. in diameter and free from pinholes, in a weighing bottle, by heating in a well ventilated oven at 100°C., for at least one hour, and weigh. Melt the dry residue from the moisture determination (or the residue by the first alternative method if it is not brown) and add 30 ml. of petroleum spirit (boiling point 40-60°C., or 60-80°C. in hot climates) and mix and macerate the sediment with the glass rod. Wet the tared filter paper with petroleum spirit, and decant the fatty solution through the paper, leaving the

sediment in the dish. Macerate the sediment and extract twice with 15 ml. of petroleum spirit and filter, keeping the paper wet by dropping petroleum spirit round the edges of the paper. Wash the sediment from the dish into the filter with petroleum spirit, and wash all fat from the inside and outside of the dish, and finally wash the paper until free from fat. Dry the paper, weighing bottle, and dish with rod at 100°C. until constant in weight. The combined increase in weight of the dish, rod and paper over the tared weights is the curd and salt in the weight of sample taken.

(a) Salt.—Transfer the paper to a clean filter funnel, wash the contents of the dish with hot water into the paper, and wash the paper until free from chloride. (If some of the contents of the paper have escaped into the weighing bottle this also should be washed into the paper.) Determine the amount of chloride by Volhard's method, and express the result as sodium chloride (salt).

(b) Curd.—The percentage of curd is obtained by subtracting the percentage of salt from the combined percentage of curd and salt.

Determination of Fat

The percentage of fat in the sample is most conveniently obtained by subtracting the sum of the percentages of moisture and curd and salt from 100. It may be determined directly by collecting the filtrate from the curd and salt in a weighed flask, distilling off the ether, and drying, with precautions to remove solvent vapour, to constant weight.

Determination of Acidity in Butter

Weigh accurately about 5 g. of butter in a dry clean flask. Add 20 ml. of ether neutralized to phenolphthalein and dissolve the fat by shaking. Add 100 ml. of 5 per cent barium (or calcium) chloride solution which has been neutralized to phenolphthalein. A close fitting cork or stopper, wetted with this solution when it is being added, should be inserted into the flask. Titrate with N/10 alkali until a pink colour persists in the aqueous layer after vigorous shaking. Calculate the degrees of acidity of the butter in terms of ml. of normal alkali required for 100 g. of butter.

1° Acidity = 0·282 per cent oleic acid.
= 0·090 per cent lactic acid.

Determination of Common Salt in Butter

Weigh 2 g. of the well-mixed sample of butter into a 250 ml. conical flask, and add 10 ml. of distilled water and 25 ml. of N/20 silver nitrate solution. Warm the contents of the flask to melt the butter and shake well. Then add 10 ml. of concentrated nitric acid and boil the contents of the flask until all the curd has dissolved; this is reached when the silver chloride precipitate is granular, the liquid has a clear lemon colour and the layer of fat is clear and free from solid material. Add 2 ml. of a saturated solution of iron alum in 10 per cent nitric acid and make up the volume to about 100 ml. Titrate the excess silver nitrate with N/20 potassium thiocyanate solution until the appearance of an orange tint persists for 15 seconds.

Determine the equivalent of 25 ml. of silver nitrate as thiocyanate, using the same volumes of the reagents, and subtract the number of ml. of thiocyanate used in the determination on the butter.

The difference gives the number of ml. of thiocyanate solution equivalent to the chloride in the amount of butter taken.

The silver nitrate solution is standardized against a solution of sodium chloride of known strength, using the Volhard method. (1 ml. N/20 thiocyanate=0·00292 gm. NaCl.)

Kohman Procedure for Butter Analysis

A rather simple yet practical method for the anslysis of butter under factory conditions is that known as the Kohman procedure (31 and 47). In this test a special balance may be employed, although the weighings can be made on a regular torsion or beam balance calibrated to weigh to 0·001 gram. The percentages of the constituents may then be calculated.

Determination of the Moisture

Mix the butter sample very well after slightly warming it, or use the sample prepared as outlined by the British Standards Institute, discussed above. Weigh 10 g. into an aluminium cup and heat it over a low flame. The contents of the cup must be mixed or stirred to prevent frothing and sputtering; heating should continue until foaming ceases and a light

brown colour appears. The cup is then allowed to cool and it is reweighed. The loss in weight divided by the original weight of the sample and multiplied by 100 gives the moisture percentage of the butter.

Determination of the Fat

To the cup containing the residue from the moisture determination, add about 100 ml. of petroleum ether and mix thoroughly with a glass rod. The cup is then allowed to stand for a few minutes, to permit the solids to settle out, and the fat-petroleum ether solution is carefully decanted off. The extraction is repeated with about 50 ml. of the ether. The cup is then slowly and carefully heated to evaporate off any of the petroleum ether remaining and to bring the residue to a dry powdery consistency. The cup is then cooled and reweighed. The percentage of fat is determined by dividing the difference between the weight after the moisture determination and the weight after the fat extraction by the weight of the sample used and multiplying by 100. The powdery residue includes only the salt and curd of the butter used.

Determination of the Salt and Curd

The dry residue from the fat determination is then dissolved in 176 ml. of distilled water. Into a white cup 17·6 ml. of this solution is pipetted, a few drops of a potassium chromate solution, containing 10 grams of potassium chromate in 100 ml. of solution, are added and it is titrated against a silver nitrate solution to a permanent brown-orange colour. The silver nitrate solution should contain 29·062 g. of silver nitrate in 1000 ml. of solution so that each millilitre required to titrate the sample prepared as outlined represents one per cent salt in 10 grams of butter, the size of the sample that should be used.

The curd is determined by subtracting the total of the percentages of moisture, fat and salt from 100.

Analysis of Ghee

The determination of the common chemical and physical properties of ghee is a problem for a well equipped laboratory and a trained analyst. The properties of butter fat, or ghee, vary rather widely with the species of animal, the feed

it receives and other factors; the purity of ghee can be determined, therefore, only by a series of determinations. It is not possible here to give the details of the procedures involved in making all these determinations. The determination of only the moisture content, saponification value and refractive index are discussed. Procedure for other determinations, namely, the Reichert-Meissl value, Polenske value, Kirschner value, acid value, melting point, phytosteryl acetate test, phenolphthalein test and others, may be found in those references from which the three that are discussed are taken (11 and 15).

Determination of the Moisture Content of Ghee

Mix a sample of melted fat well with a glass rod and accurately weigh into a tared dish (previously cleaned, dried, and cooled in a desiccator) about 10 g. of the properly drawn sample. Heat the dish containing the fat in an air oven at 105°C. to constant weight. Ordinarily, the time required for drying should be about 3 to 4 hours. After the moisture contained in the fat is completely driven off, cool the dish in a desiccator to room temperature and weigh accurately.

$$\text{Moisture content} = \frac{\text{weight of moisture given off} \times 100}{\text{weight of fat taken.}}$$

Determination of the Saponification Value of Butter Fat

Weigh accurately about 2 g. of the butter fat into a flask and boil for one-half hour under a reflux condenser with 25 ml. of approximately N/2 alcoholic potassium hydroxide. Determine the excess of alkali by titration, while the solution is still hot, with N/2 hydrochloric acid, using 0·5 ml. of a 1·0 per cent alcoholic solution of phenolphthalein as indicator.

Make a blank determination upon the same quantity of the potassium hydroxide solution at the same time under the above conditions.

If X=volume in ml. of N/2 acid required for the blank,
and Y=volume in ml. of N/2 acid required when the butter fat is used,
and W=weight in g. of butter fat taken,
then the Saponification Value is $\frac{(N-Y) \times 28 \cdot 05}{W.}$

Determination of the Refractive Index of Butter Fat

The refractive index should be read on an Abbé refractometer, or the equivalent reading taken on a butyro-refractometer, at the temperature of approximately 40°C., taking care that the fat has reached the temperature of the instrument before the reading is taken. To determine the corresponding reading at 40°C. X is added to the observed reading for each °C. above, or subtracted for each °C. below, 40°C. *pro rata.*

X for butyro-refractometer =0·55

X for Abbé refractometer =0·000365

The correctness of the adjustment of the instrument should be tested before taking a reading.

Milk and Metals

A considerable amount of dairy equipment is made from metals or their alloys. Milk and milk products come into contact with these materials, many of which are easily corroded by or are soluble in milk. Some of these metals combine with milk constituents to produce salts which give a metallic flavour to the milk. Some of these salts are toxic, although it is questionable whether there is any accumulation of such metals and their salts in the human body (21). Certain of the metals commonly used are acted upon by the alkali materials used for washing powders in the sanitation of the milk plant ; some transmit heat very slowly, while others are soft and therefore not satisfactory for certain purposes. Some are unstable in the presence of chemical sterilizers. The metals used in the manufacture of dairy utensils and equipment are mainly iron, copper, tin, zinc, aluminium, nickel and chromium. Alloys of these which are sometimes used are brass, bronze and stainless steels. Combinations of two of these metals, in which one is coated with another, are employed, particularly tin coated copper or zinc coated, that is galvanized iron.

The requirements which must be met by a dairy metal depends somewhat upon the use to which it is to be put. Milk cans and pails, for example, are liable to rather rough use and must, for this reason, be made of durable material, such as iron or stainless steel. Pasteurizers and coolers

must be made of materials through which heat passes quickly. Copper is very useful for this purpose, except that it is rather soluble in, and imparts a metallic flavour in milk. When coated with tin, however, these criticisms are largely overcome. Brass and bronze both contain copper and must be employed accordingly. Allegheny metal, a stainless steel containing 18 per cent chromium and 8 per cent nickel in steel, commonly called 18-8 chrome-nickel steel, is the best alloy yet known for use in dairy equipment. It may be distinguished from chrome-steel, another group of stainless steels, containing 13 to 14 per cent chromium and no nickel, by the fact that it is non-magnetic, while the 18-8 chrome-nickel steel is magnetic (47).

Copper is one of the most easily fabricated of the metals commonly used. Tin is one of the most resistant to the acids and salts of the milk, to the alkali washing materials and to chemical sterilizers. Tin coated copper is, therefore, a very useful combination for many purposes. It does not stand hard use satisfactorily, such as cans and pails must withstand, so is not so useful for their manufacture as tin coated iron. Iron is slightly soluble in milk and milk products and, like copper, produces metallic flavours in milk rather rapidly. Allegheny metal is very hard, hence not easily worked. It is one of the most durable alloys for this purpose, however, that is known. Consequently it has a very wide use in the dairy industry, as it has in any food industry. This alloy may be used in thin sheets where heat exchange is required, or thicker sheets for equipment requiring greater stamina. It takes a high polish and is not liable to tarnish when exposed to milk products, alkali washing powders, chemical sterilizers or the moist atmosphere of the creamery. Its general appearance adds much to that of the creamery.

Characteristics of the metals listed above which influence their use in the dairy are as follows:

Iron

Hard, durable and relatively cheap. It is soluble in milk, producing toxic salts; it is attacked by washing powders, neutralizers, chlorine compounds and brine.

Copper

Soft and highly soluble in milk, producing toxic salts having an intense bitter and puckering flavour and which actively oxidize and catalyze chemical changes, particularly in the fat. The heat transmitting ability of copper is very high. The flavour of copper salts is detectable in concentrations as low as from 2 to 4 parts per million in milk.

Tin

Very soft, heavy, but only slightly soluble in milk. The salts produced are sufficiently inert that no damaging effects on the milk products occur (47). This metal is too soft to be used by itself. It is only used, therefore, as a coating, usually on copper or iron. Strong abrasives must be used with care as washing materials when cleaning tin coated surfaces.

Zinc

Soft, fairly expensive and soluble in milk, producing toxic salts. In combination with iron as a plating, it protects the iron from galvanic action, but its own salts are probably as toxic as those of iron.

Aluminium or Aluminum

Hard, light in weight and fairly expensive. This metal is very resistant to the action of milk constituents; salts which are produced have only a slight metallic flavour and no toxic effects. It is highly unstable, however, in solutions of alkalis used for washing powders, although this may be overcome by the addition of a small amount of sodium silicate to such solutions (47). Because of the high electrolytic sensitivity of this metal, simultaneous contact of milk with aluminum and another metal is to be avoided. It possesses a high heat transmitting ability.

Nickel

Hard, but soluble in milk, giving slightly toxic salts.

Chromium

Very hard and very stable in milk, but quite expensive.

CHAPTER VI

DAIRY BACTERIOLOGY

Micro-organisms are so tiny that a microscope must be used to make them visible individually. Of those encountered in milk and milk products, namely, bacteria, yeasts and moulds, bacteria are probably the most common. Bacteria are unicellular fungi which occur as spherical, spiral or cylindrical cells and which reproduce by fission. Fungi are plants which have no proper flower, which are without chlorophyll and feed on organic matter. Bacteria measure from less than one micron (1/1000 of a millimetre or 1/25400 of an inch) to as much as 40 to 60 microns long. The common spherical bacteria are usually less than two microns in diameter.

As many as 16 billion bacteria may weigh only 1/1000 of a gram. Milk may contain several hundred million, possibly several billion, organisms per millilitre. Fresh milk, however, may contain less than 100,000, possibly as little as 5,000 to 10,000 per millilitre if carefully produced and handled.

Like higher forms of life, bacteria make use of certain chemical materials as food and produce others as by-products of the physiology of their life processes. Most bacteria produce what are known as extra-cellular enzymes or chemical ferments. Enzymes produced by micro-organisms are excreted by the cells so that the chemical materials in which the cell is imbedded or upon which it rests and which immediately surround it are acted upon by these enzymes. They usually initiate chemical changes that may be extremely complicated but which result in the formation of specific end-products which will depend upon the organism concerned and the material involved.

Methods of Reproduction

Bacteria reproduce by fission. Reproduction by fission, usually by binary fission, involves a gradual constriction of the cell on opposite sides. As this constriction progresses, two cell parts or sections are formed into which the divided cell

contents gather. This continues until the two sides meet. The cell, known as the mother cell, then separates into two small or daughter cells which pursue their functions independently. The lifetime of one generation of bacteria may be as little as 20 to 30 minutes. One single organism may, therefore, conditions permitting, give rise to millions of organisms in a very short time. This fact is of importance in considering the effect of bacterial growth on the quality of milk and milk products.

Under some conditions, particularly those adverse to optimum growth, certain bacteria may produce what are known as spores. At this time the major portion of the cell contents gathers into a specialized structure known as a spore in which it may survive extremes of temperature and humidity. Many spores may even survive boiling. Most spore forming organisms are derived from the soil.

Yeasts reproduce in two ways, one of which, known as budding, is similar in some respects to fission. The process of reproduction by budding involves the protuberance on different parts of the cell body of tiny portions of the cell contents, much as droplets of perspiration on the surface of one's body. These small particles or buds soon separate from the mother cell to form a new cell. Another method of reproduction, known to some species of yeasts, involves the formation of numerous tiny bodies within the mother cell. In due time the wall of the mother cell bursts, releasing these small bodies each of which may establish a separate existence (31).

Moulds may reproduce by the separation of hyphae or body structures into two or more parts, each of which continues an independent existence. They may also reproduce sexually by means of fruiting bodies. At the terminal end of the aerial hyphae specialized bodies appear in very great numbers. These produce what are called spores. As the spores ripen they become dry and easily carried away by slight air movements. Whenever they find conditions satisfactory where they finally come to rest they will germinate to produce a new mould hyphae. The innumerable hyphae which combine to produce the mass of branching interwoven threads, which is visible to the naked eye, are collectively known as the mycelium. Mould spores, as is true of bacterial spores, may survive for long periods of time under extremely adverse temperature and humidity conditions.

Bacteriological Terminology

Spherical bacterial cells are usually called cocci. Some of these, known as streptococci, tend to reproduce by repeated fission in the same plane and without separation, thereby forming chains; others, known as staphylococci (pathogenic forms) or micrococci (nonpathogenic forms), divide in diverse planes before separating, thus forming irregular groups of cocci. Others, known as tetracocci, form an aggregate of four cocci; still others, called sarcina, by their mode of division build up cubes or packets of eight cocci. Rod-shaped or cylindrical bacteria vary greatly in size and relative dimensions of length and breadth and belong to many generic groups. Thus some of the larger and longer bacteria belong to the genus *Bacillus*, for example, *Bacillus subtilis*; some of the shorter and more slender ones belong to the genus *Bacterium*, for example, *Bacterium coli*. Spiral-shaped bacteria have a diameter: length ratio somewhat similar to bacilli, but instead of appearing straight or cylinder-shaped they are spiral-shaped, much like a screw or augur.

Certain physiological characteristics of different bacteria are described by the use of special terms. Pathogenic bacteria are those which produce diseased conditions in plants or animals. The nonpathogenic bacteria may be undesirable under certain conditions, such as acid producing bacteria which commonly cause milk to turn sour, but do not produce diseased conditions as others do. Most of the common micro-organisms grow at temperatures ordinarily between 50 and 100°F., or those temperatures ordinarily tolerated by living beings. Those bacteria which enjoy or require low temperatures are called cryophilic. Such organisms are rarely encountered in the dairy industry. Those which tolerate but which do not enjoy high temperatures are called thermoduric; those which enjoy or require high temperatures are called thermophilic. Such organisms are frequently encountered in the dairy, particularly in pasteurization equipment. The majority of the organisms encountered in dairying are mesophilic, or those which enjoy or require an intermediate temperature range in which to grow. All bacteria have minimum, maximum and optimum growth temperatures. The ability of different species of mesophilic bacteria to withstand

extremes of temperature is variable. The pathogenic organisms ordinarily found in milk in western countries include *Mycobacterium tuberculosis*. This is the most heat resistant of the pathogenic organisms ordinarily encountered in this food product, at least in the West. The temperature-time combination at which it is destroyed, known as the thermal death point, is 140°F. for 20 minutes (41). The usual pasteurization exposure is designed, therefore, to destroy this organism, since the exposure that will destroy it will also destroy most other pathogenic bacteria present. The vegetative forms of spore forming organisms are not greatly heat resistant, but whenever they are present great numbers of their spore forms or spores are usually also present. In order to destroy the spores very intensive heating exposures may be required. The bacteriological sterilization of certain equipment in the laboratory, for example, may require intermittent boiling for one hour on three consecutive days.

Bacteria which produce colours are called pigment formers or are considered chromogenic. Those capable of moving about independently are said to be motile.

Lipolytic organisms are those which effect lipolysis or the chemical breakdown of fats. Proteolytic organisms are those which cause proteolysis or effect decomposition of proteins. Other organisms may be acid-formers; some may be gas-formers while still others may bring about changes in the flavour or physical characteristics of the nutrient medium, possibly milk or one of its products in which they may be growing. Such organisms will be dealt with in more detail later.

The Occurrence of Bacteria

Bacteria are found practically everywhere. The surgeon in his operating theatre must take very special care to prevent contamination of the incision he makes during an operation. His scalpel and other instruments must be thoroughly sterilized. The garments he wears must be sterile when he uses them. He must wear sterile rubber gloves which he puts on only after thoroughly washing his hands with clean water and soap, followed by rinsing in an antiseptic solution. He wears a mask over his mouth and nose to avoid contaminating his subject by those bacteria that he may discharge while breathing. The air in the operating

theatre must be especially cleaned to eliminate any possibility of it carrying bacterial cells or spores which might cause infection at the site of the operation. The use of aseptic practices has been one of the most important factors in the development of the skill and science of surgery.

The food manufacturer is well aware of the absolute necessity of bacteriological sterilization of his products and the containers in which they are placed in order to prevent spoilage. The soil scientist is familiar with the wide distribution of bacteria which play so important a part in soil formation or plant nutrition.

The dairyman likewise is familiar with the spoilage of milk or milk products if proper care is not taken to assure that degree of sanitation which will prevent such difficulty.

The human body continuously combats bacterial infection because of the presence at all times of various types of bacteria in the air from which oxygen is supplied, in the water so necessary to life and good health and in the food materials that must be consumed in order that life and health may be maintained. Every person has experienced a diseased condition resulting from bacterial infection. Innumerable diseases, such as typhoid, cholera, and others are caused by bacteria. Whenever the human body becomes slightly weakened either locally or generally a diseased condition may result from bacteria which are always present, seemingly seeking an opportunity to infect the living body.

The Growth Phases of Bacteria

The activity of a bacterial species in a suitable environment can be divided into three phases. The first of these is known as the lag phase during which the organisms seemingly settle into their environment, accustom themselves to it and grow somewhat before reproduction begins. This is followed by the second phase, known as the logarithmic growth phase, during which time the activity of the organisms, as measured by their increasing numbers, is very rapid. The lag phase may continue for an hour or so after the medium has been inoculated. The logarithmic growth phase may continue for several hours, depending upon the genral conditions provided by the environment and upon the extent to which the organism involved can survive in increasing numbers or in

increasing concentrations of the by-products of its own physiology. The third phase is known as the resting phase. At this time the organisms seem to have spent themselves; there is a consequent cessation of their normal activity. These three phases may, in a sense, be compared to adolescence, maturity and senescence in higher forms of life.

Bacteria in Milk

The importance of bacteria in dairying is three-fold. Firstly, their effect upon the keeping quality of the products involved; secondly, the part they play in the development of the desirable flavours and odours in certain manufactured milk products; and thirdly, the possibility of bacterial diseases being transmitted to man through milk (41). The sources of bacteria in milk may be listed as internal or external.

Internal Sources

As milk is drawn from the udder it regularly contains bacteria whether the udder is normal, injured or infected. Those bacteria which come from a normal udder are usually micrococci which grow slowly in milk and which are usually present in such small numbers that they are of no practical importance. Udders which are normal, however, eject milk containing large numbers of white blood cells or leucocytes. These seem to be discarded during the secretion and ejection processes in the gland. Just why this should happen is not fully known unless, as has been claimed by some, the outer sides of the secretory cells disintegrate as the milk is ejected into the collecting system. It is explained in Chapter III, however, that this theory of milk ejection is not widely accepted. Milk which is drawn aseptically, or in such a manner as to exclude any possibility of contamination from external sources, may contain large numbers of bacteria as well as blood cells, particularly leucocytes, and body cells. The bacterial count of milk drawn in this way from a healthy udder is relatively low, but may be several thousand per millilitre.

It is not often that bacteria found in the blood stream gain entrance into the milk for, as is stated elsewhere, there is normally no direct passage of the blood through the secretory tissue during the secretion or ejection of milk. Such a condition may occur, however, in the case of injury or

severe infection. When bleeding occurs within the udder, erythrocytes or red blood cells will be found in the milk in numbers proportional to the degree of bleeding.

Cows suffering from mastitis, or bacterial udder infection, may produce milk containing up to several hundred thousand bacteria per millilitre. The most common causative organism of the infection is *Str. agalactiae*—at least in western countries—with certain staphylococci next in importance. The former is harmless to man (41), while the latter, principally *Staph. aureus*, may be responsible for the production of enterotoxins in milk, under certain conditions, which cause food-poisoning in man (78). The haemolytic or blood-splitting streptococci which cause septic sore throat in man have also been associated with udder infections (93). The leucocyte count of milk from an infected udder is generally greater than 500,000 per millilitre, while that of milk from a healthy udder is usually less.

External Sources

Although milk may contain large numbers of bacteria as it comes from the udder, the main sources of bacteria in milk are ordinarily external. The majority of these bacteria, as much as 70 to 80 per cent of them, come from the milking pail and other utensils in which the milk is handled. The coat of the cow may be an important source of bacteria unless care is taken to clean the body of the cow properly before milking. The man handling the animal or milk may be a source of contamination if his clothes and hands are dirty or if his personal habits, such as his manner of coughing and sneezing while near or actually handling the milk, are not careful. The atmosphere in which the milk is produced and handled may also be a source of considerable contamination. If the dust and dirt content of the air is high, a considerable amount of such material containing large numbers of bacteria will settle from the air into the milk as it stands exposed subsequent to being drawn from the udder. Another important source of bacteria in milk is flies. The body of the fly is covered with fine hairs among which dust and other debris may collect. The fly, furthermore, enjoys the environment of decayed or spoiled materials and filth equally as much as it

enjoys the environment of the dairy. As flies crawl about the pieces of equipment or as they drink the milk or fall into it they contribute considerably to its contamination.

The proper sanitation of dairy equipment cannot be over emphasized. The construction of the equipment, the material from which it is made and the manner in which it is cleaned, all play a part in determining the extent to which it may serve as a source of bacterial contamination of milk. It has been stated that the utensils and equipment are responsible for 70 to 80 per cent of the bacterial contamination ordinarily found in milk. This indicates, at least in part, the need for considerable care in the washing and sterilization of dairy equipment.

Milk utensils should, first, be rinsed in cold water, followed by a thorough washing with a brush or cloth, using hot water containing a washing compound. This should be followed by again rinsing in warm water and then sterilizing, after which the utensils should be thoroughly dried by allowing them to drain and, where possible, exposing them to direct sunlight. A cloth should not be employed for the drying of dairy equipment. A fuller discussion of the methods of washing dairy utensils and equipment will be found in Chapter VIII.

A symbiotic relationship may exist between two or more species of bacteria resulting in the production of a particular flavour or odour in the milk product. Symbiosis involves the simultaneous growth and function of two separate species of living beings which mutually contribute one to the other. The ordinary white ant, for instance, produces in its intestinal tract an environment, with respect to temperature and humidity, required by a particular species of bacteria. The material consumed by the white ants, that is wood fibre, cannot be used directly as food since the digestive system of this ant is not able to digest such materials. The bacteria found in the intestinal tract, however, make use of this wood fibre as a food and, with conditions otherwise provided in that environment, utilize considerable quantities of it, producing at the same time certain by-products which serve as food for the white ants. Neither can live without the other.

The more practical application of this phenomenon, particularly so far as the dairyman is concerned, is the action, known as associative action, of at least four species of bacteria in

the production of a satisfactory butter culture. This will be described later. Associative action of other organisms occur in the advanced decomposition of milk when a bitter flavour begins to appear and when the colour of the milk begins to disappear. Such action is also involved in the curing of many common types of cheese.

The Action of Micro-Organisms in Milk

The biological decomposition of milk involves principally the lactose, protein, fat and ash. The more common changes which result from the action of micro-organisms, *viz.*, bacteria, yeasts and moulds, on these constituents of milk are : lactose breaks down to form lactic acid, gas and/or alcohol; proteins decompose to form amino acids and ultimately ammonia; fat breaks down into free fatty acids and glycerol; the changes in the salts of milk depend upon the salt or salts involved as, for example, the production of acetylmethylcarbinol and diacetyl, the materials responsible for the fine flavour and aroma of ripened cream butter, by the fermentation of the citrates of milk. Little is known at the present time about the affects of bacterial action upon the vitamins or the vitamin content of milk.

Bacterial decomposition of lactose results from the action of certain bacteria, particularly *Streptococcus lactis*, in milk. As the formation of lactic acid occurs, the lactose content of the milk is reduced and the lactic acid content is increased, simultaneous with the increase in the bacterial content of the milk. One of the first evidences of this action is the occurrence of a slight acid or sour flavour in milk. As the action progresses at ordinary temperatures the milk will become quite sour, followed by coagulation, that is, the precipitation of casein which takes place at a pH of 4·7. A semi-solid product known as curd results. No other physical or chemical changes are obvious. According to Hammer (41), bacteria which produce lactic acid are *Str. lactis*, *Str. thermophilus*, the lactobacilli, *Str. liquefaciens*, and certain other bacilli.

The bacilli, other than lactobacilli, may also produce gas, usually carbon dioxide, during the fermentation of lactose. Yeasts, however, are largely responsible for the production of gas in milk and cream. This is probably not true in cheese,

however, in cases where gas formation occurs during storage. Here certain bacteria, of which *Clostridium welchii* is an example, are more commonly responsible.

The bacterial decomposition of protein involves the breakdown of the casein, lactalbumen and lactoglobulin with the formation of peptones, amino acids, ammonia and possibly free nitrogen (41). Proteolysis or peptonization is not desirable in fluid milk intended for market purposes. It is, however, especially important in the manufacture of most varieties of cheese, especially those which must be cured by holding for a period of time at a given temperature in order that the proper flavour and aroma may develop. Proteolysis usually involves the formation of alkali, as the bacteria attack the salts of acids present, converting them into alkaline carbonates (31). A sweet curd, the production of which is known as sweet curding, may be formed during proteolysis by the action of such organisms as *B. subtilis*. This condition is manifest by the formation of curd without acid formation. It results from the production by the organisms involved of an enzyme that acts in the manner of rennet (31).

There are instances in which acid producers, specifically *Str. lactis var. hollandicus*, or alkali producers, such as *Alkaligenes viscosus*, produce a peculiar physical condition in milk known as ropiness. Milk which is ropy is liquid but very viscous and sticky so that as it pours it forms long ropes or threads. No noticeable chemical change occurs in such milk. It is, therefore, as stated by some authors (31), more annoying than dangerous. Under certain conditions such milk may be desired; we are told that the Finns make considerable use of ropy milk as a beverage.

Lipolysis is the breakdown or decomposition of lipids or fats. Lipolytic organisms are encountered in milk. Such organisms hydrolyse fat, liberating fatty acids and glycerol. Certain of the fatty acids of milk, particularly butyric and capric, have specific and strong odours. As lipolysis frees such acids, strong and therefore quite noticeable and undesirable flavours are produced in the milk product. Such a condition is referred to as rancidity. It may be produced by the action of *Pseudomonas fluorescens*.

The production of certain flavours in milk and its products by the action of bacteria, yeasts and moulds has been partially

discussed already. The causes of acid, bitter and rancid flavours have been stated. These, together with the fine delicate flavour characteristic of good quality butter, are the principal flavours produced by the action of micro-organisms. Fishiness is sometimes encountered, although not as commonly as those just named.

The flavour and aroma of butter is influenced by the nature of the cream from which it is made and the manner in which it is handled and processed. Certain flavours depend upon the volatile acid content of the butter fat or the materials which may find their way into the fat either through the cow, principally feed flavours, or by absorption resulting from exposure. Causes for variations in the volatile acid content of butter fat are discussed in Chapter IV. The absorption of materials by this fat depends entirely upon the care given in the handling of the product in which it is contained and from which butter is made. Exposure of milk or cream to kerosene, cabbage or onion, for example, will regularly cause flavours in the cream characteristic of the material invloved; scorching of the cream during pasteurization may produce a pronounced scorched flavour in the butter, principally in the curd fraction; the fat readily absorbs this flavour. Such flavours cannot be removed successfully from the cream during the manufacture of butter, although aeration may help.

The flavour resulting from bacterial action in milk or cream which is of considerable commercial significance in the butter industry, and which may become of importance in the making of high quality ghee, is that which is produced by the use of a good butter culture. Since such cultures are discussed in more detail later on, it is sufficient at this time to state that this flavour, a slight acid and strong nutty flavour, is that which is characteristic of fine flavoured butter.

There are other flavours, however, which may be found in butter, although they are probably not of such importance as that just described. A metallic flavour may be produced by bacterial action. This particular flavour may be considered one of the bitter flavours that are so numerous. Hammer (41) has reported the appearance of several other flavours in milk, such as potato, fruity and soapy, which were of bacterial origin.

A fishy flavour is produced by the action of *Ps. fluorescens* (19),

Proteus ichthyosimus (41) or *Oidium lactis* (47) on lecithin. Lecithin is closely associated with butter fat. It dissolves in a salt solution, especially if acid is present. Iron and copper salts catalyse its hydrolysis producing choline; the oxidation of choline gives trimethylamine, the material responsible for a fishy flavour in milk and milk products. This flavour defect may be found in butter, principally salted butter made from high acid cream. It usually appears after extended storage, although it may be present in fresh butter made from unpasteurized or poorly pasteurized cream. The higher the storage temperature the sooner fishiness appears and the more pronounced it is. Its intensity is never very great, however, but it is particularly objectionable in butter.

Several different colour fermentations may occur in milk or its products as a result of the action of bacteria or other micro-organisms. A red colour is produced by *M. roseus* (19) or by the action of certain yeasts. This defect is most commonly noted in varieties of fresh soft cheese, such as cottage cheese. It may occur in milk or cream after it has stood for considerable time.

A yellow discolouration is produced by organisms such as *B. synzanthus* (19). Certain yeasts and moulds may also produce this colour in milk or its products.

Cases of the appearance of a blue colour in milk have been reported by Hammer (41) who explains that the causative organism in *Ps. cyanogenes*, an organism Chalmers (19) calls *B. cyanogenus* (Flügge). Both agree that the blue colour results from the associative action of this organism with *Str. lactis* which produces acid. In the absence of acid, only a brownish tinge may appear in a milk culture of the organism. Yeasts and moulds are rarely if ever responsible for the production of this particular colour, except for the blue moulds of the genus *Penicillium*.

M. niger may produce a black colour in milk (19). Species of mould of the genus *Alternaria* are also responsible for the occurrence of black colours on several milk products, principally butter and cheese (41). A green fluorescence has been observed that is a result of the action of *Ps. fluorescens* (19). Certain moulds, mainly species of *Penicillium* (41), are also responsible for this particular colour. A white colour, although not easily detected in milk and certain of its products, is produced by certain yeasts

and moulds; an example of this is the action of *Penicillium camemberti* in camembert cheese.

The Bactericidal Action of Milk

Freshly drawn milk has a bactericidal property, that is, it prevents the growth of bacteria for a short period of time. The duration of this action may be only an hour or it may extend to several hours, depending upon the type and extent of bacterial contamination and the temperature at which the milk is held. Doubtlessly there are variations from cow to cow, possibly from day to day for the same cow, in the effective duration of this property. The effect of this property of milk must not be confused, however, with the fact that those bacteria which gain entrance to the milk, that is, from the utensils and the air, immediately after it is drawn from the udder, will pass through a lag phase before their activity becomes greatest.

The general lack of refrigeration facilities for the proper handling of milk in the dairy and during transit makes it imperative that, having prevented contamination so far as possible in the production and handling of milk, it is delivered to the customer in the shortest possible time in order that it is received before noticeable bacterial action has taken place, that is before any bacterial fermentation or decomposition has occurred. The ability of milk to retard bacterial growth for this short period, due to its bactericidal action, is consequently of considerable commercial importance.

Bacteria and Milk Products

Three points have been given to indicate the significance of bacteria in milk. Two of these had to do with the preservation or improvement of the quality of milk and milk products. The bacteriology of milk products, therefore deserves some attention here.

Dahi

Dahí is a product obtained by the coagulation of milk resulting from the production of acid by bacteria. The principal organisms involved, therefore, are those which ferment lactose, probably most commonly *Str. lactis* and *L. acidophilus* or *L. bulgaricus*. Other organisms are involved, but they are less im-

portant. Organisms which are responsible for the production of flavours other than acid flavours may play a part. It is doubtful whether the commercial manufacture of *dahí* involves the use of specific organisms other than acid-producers, although in the common household method of making *dahí* it is likely that other organisms do play a part. If they do, they may be those which ferment citrates with the production of flavour producing materials discussed under butter cultures.

Ghee

The manufacture of a fine quality ghee may involve the use of cultures with which the cream or milk from which ghee is to be made may be cultured to bring about the production of certain desired flavours. In the manufacture of most of the ghee made in India the method commonly followed is called the village method. This involves the making of *dahí* which is then churned to produce village butter or *makkhan*. Whatever organisms are involved in the making of *dahí* under village conditions are involved, up to this point, in the making of ghee. Since, however, a common practice is to hold the *makkhan* so produced for as much as three to five days or longer before it is heated, another stage at which bacteria play a part is encountered. This includes the growth and activity of bacteria in the *makkhan* during the period of time it is held before heating. Ordinarily this involves whatever bacteria may normally be present, and not specific organisms which may be added. As has been stated, however, this procedure, which is an extremely common one, does not make possible the production of the best ghee. Considerable work is yet to be done on the bacteriology of ghee production so that it is not possible at this time to say what procedure would give the best results. It may be that use of the common butter cultures may be made or it may be desirable to use cultures of entirely different organisms to make possible the production of the best quality of ghee.

Khoá, Chhená, Khír and *Rabaṛí*

Bacteria are not employed in the manufacture of *khoá*. In fact the best possible quality of milk must be used to be sure it will not coagulate during the prolonged heating at boiling

temperature. Such milk must be as clean and as free of bacteria as possible; fresh milk is therefore best for this purpose. As is discussed elsewhere, as the development of acid takes place in milk its heat coagulation point is reduced. The treatment given to milk in the making of *khoá* requires that the most heat-stabile milk available be used.

The growth of bacteria or other micro-organisms in the finished *khoá* will reduce its market value very rapidly. The surface contamination of *khoá* not immediately utilised, particularly that made in the villages and sold in a nearby urban market, includes yeasts and moulds as well as certain bacteria. These organisms will cause acid production and proteolysis more commonly than lipolysis.

The bacteriological consideration in the selection of the milk to be used for making *chhená*, *khír* and *rabaṛi* and in the handling of the products thereafter are much the same as for *khoá*.

Butter

The main bacteriological consideration in butter making is the culturing of the cream from which butter is made. Butter cultures are milk cultures of several organisms, usually of two types, *viz.* (1) those which produce lactic acid by the fermentation of lactose and (2) those which produce acetylmethylcarbinol, diacetyl and 2, 3-butyleneglycol, the products responsible for the fine delicate flavour in butter, by the fermentation of citrates or citric acid present in milk or cream. Organisms of the first group, according to Hammer (41), are primarily *Str. lactis*, although other lactic acid-formers may be involved. Organisms of the second group are *Str. citrovorus* and *Str. paracitrovorus*. The lactic acid producers are the first to become active in such cultures. They continue their activity until a pH of about 4·7 is obtained. At this pH, the citric acid fermenters become active, converting citric acid into the products just named. The action of citric acid fermenters is rapid. Acetylmethylcarbinol is first produced by the fermentation of citric acid. This is followed by its oxidation to produce diacetyl. The former product is odourless but is a source of the latter which largely accounts for the flavour and aroma that results. If this fermentation is permitted to proceed too far, the production

of 2, 3-butyleneglycol, by the reduction of diacetyl, prevents further formation of the important flavour ingredient, that is, diacetyl. In the management of a butter culture, therefore, it is important that the culture be used or that this activity be stopped, most commonly by cooling it, at that point at which the maximum quantity of diacetyl has been produced. In terms of time, this involves a period of as little as 30 minutes within which the culture will produce the best results in butter making. Cream may be ripened by the use of such a culture as just described, churning being carried out when the maximum diacetyl is produced. The quantity of diacetyl may be increased by adding citric acid directly to the cream in quantities varying up to those normally found in milk or by culturing the cream under a pressure of 30 to 40 pounds to the square inch.

During butter storage, acid production may continue simultaneously with proteolysis and lipolysis. The presence of salt retards bacterial changes in butter during storage, although certain fermentations do occur in salted butter. Micro-organisms, mainly moulds, freely attack the surface of butter in storage unless special care is taken to prevent this.

Cheese

The micro-organisms used in the making of cheese include mainly bacteria and moulds. Certain types of soft cheese are made by heating *dahí* with some agitation. This brings about separation of the curd from the whey. The bacteriology of *dahí*, therefore, is involved in the making of this type of cheese. In the making of cheddar cheese a bacterial culture is used which contains both acid producing and proteolytic bacteria. These characteristics may be combined in a single organism, such as *Str. liquefaciens*. The acid produced by such organism facilitates the action of rennet during the process of the making of the cheese. During the early stages of curing of such cheese the acid producers continue their activity, providing an environment which enables the proteolytic organisms to break down the curd or protein portions of the cheese into products responsible for the desired flavour and aroma as well as body and texture.

The type of proteolytic organism required in the making of good cheese varies from one kind of cheese to another. *Str.*

liquefaciens seems to be one of the most important of these organisms in the curing of cheese.

Certain types of cheese, such as roquefort and camembert, are cured by the action of moulds. In the former case the mould employed is *Penicillium roqueforti*, while *Penicillium camemberti* is the mould employed in curing of the latter. Both these moulds are aerobic, that is, they require air or oxygen in order to grow, and are, therefore, inclined to grow only at the surface. The penetration of the mould to the centre of the cheese is facilitated, in the manufacture of roquefort cheese, by inoculating the curd with mould as it is put into the hoops and by punching holes into it during curing. *Penicillium roqueforti* is known as a green mould since its fruiting bodies are green in colour. Growing in a thick mass, as it does in and on the cheese, it gives the cheese a green mould appearance. The fruiting bodies of *Penicillium camemberti* are white so that this mould is known as a white mould; it produces a white mould mass on the surface of the camembert cheese.

Ice Cream

Bacteria are not desired in the making of ice cream. The number and types of bacteria that will be present in ice cream, however, will vary with the bacterial content of the raw materials, the nature of the processing and the extent to which contamination occurs. One rather important consideration in reference to the bacteriology of ice cream is the fact that freezing destroys very few, if any, bacteria. The mesophilic and thermophilic types remain latent while in the frozen condition, only to continue their life processes, apparently as vigorously as ever, as the temperature is increased. A low bacterial content in ice cream cannot be brought about by freezing. Ice cream of low bacterial count can only be produced by controlling the quality of the raw materials, by properly pasteurizing the mix and by preventing contamination.

Acids of Bacterial Origin as Food Preservatives

The universal occurrence and the rapidity of growth in milk of *Str. lactis* makes the acid fermentation of milk the most common bacterial change known in that product. The first production of *dahi* and other fermented milk products,

therefore, was very likely not an invention coming as a reward for continued and diligent study of the problems involved, but a discovery made rather soon after man began to make use of the milk of domestic animals for food purposes. Considerable use is made of fermented milk, in certain countries at least, since it keeps longer without refrigeration or boiling than sweet milk and has been found rarely, if ever, to be detrimental to human health.

The preservation of food materials by use of acid is a very old practice. This method of preservation is possible because the acid is usually produced in such quantities that either those bacteria which are responsible may cease to grow because the concentration of acid becomes too great for them to tolerate, or other organisms which may continue acid production or which may bring about proteolysis or other types of decomposition cannot tolerate it.

Silage is a food material for livestock that also may be preserved by acids produced by bacterial action, although the continued respiration of the cells of the fodder plants, after ensiling plays a considerable part.

Preserving Milk and Milk Products by Refrigeration

Since most bacteria found in milk grow best at temperatures between 65° and 90°F., temperatures outside this range tend to prevent their growth, which may occur rather slowly even as low as 50° or as high as 100°F. Milk may be preserved for a considerable period of time by holding it above or below this range where the activity of bacteria, that is, the speed with which they grow and reproduce, is retarded. Since, however, the occurrence of thermoduric and thermophilic bacteria is more common than that of the psycrophils, refrigeration at temperatures below 50°F. is found to be more satisfactory as a means of preserving milk or its products than heating to temperatures greater than 100°F. Refrigeration temperatures for milk and milk products are given in Chapter VIII.

Methods of Counting Bacteria

Three common tests employed in determining the bacterial content or the bacterial quality of milk and its products are the reductase test, the bacterial plate count and the Breed count.

The Reductase Test

A biological indicator is employed in the reductase test to show when changes in the oxidation-reduction potential, or the electric potential, in the material under test take place. The indicator commonly used for the examination of milk is methylene blue, although more recently resazurin has been used. The electric potential, or Eh, of fresh milk varies from plus 0·20 to plus 0·30 volts. As a result of the growth of bacteria in milk, utilizing the oxygen that is present, this potential may drop as low as minus 0·20 volts. Those indicators which show colour changes, when mixed with milk, somewhere between Eh values of plus 0·30 and minus 0·20 volts are used in the reductase test to show the change of the oxidation-reduction potential resulting from bacetrial growth.

The apparatus to be used must be sterilized by boiling. Ten millilitres of milk are added to one millilitre of methylene blue solution in a test tube. These are then thoroughly mixed, the test tube is stoppered and incubated in a water bath in the dark at 37°C. Some authorities advise inverting the tubes every thirty minutes during incubation to prevent the rising of the fat which sweeps a large portion of the bacteria to the surface of the sample. The reduction time is the time required, after mixing the milk and the dye, for the bluish-green colour to disappear; and this is taken as an indication of the bacterial quality of the sample.

Milk is classified on the basis of this test into four classes, each of which is considered to cover a certain range of bacterial count. The four classes are shown below with the approximate keeping quality and bacterial count to which their reduction times correspond (19).

Class of milk	Reduction time	Approximate keeping quality in hours	Approximate bacterial count per ml.
Class 1, good milk	5½ to 9 hours	40	500,000 or fewer
Class 2, average milk	2 to 5½ hours	30	500,000 to 4,000,000
Class 3, bad milk	20 minutes to 2 hours	10	4,000,000 to 20,000,000
Class 4, very bad milk	20 minutes or less	less than 10 hours	20,000,000 or more

An indicator which has a reduction point (changes colour) between the electric potential of fresh milk and that at which methylene blue reduces should prove to be a more sensitive indicator than this dye. Considerable work has been done with resazurin in various countries. Reports on the possibility of the resazurin test being more reliable for indicating the bacterial quality of the milk samples are somewhat variable. There is, however, fairly general agreement that the use of this indicator gives more information about the nature of the flora of the sample than is given by the use of methylene blue.

The technique of the resazurin test is similar to the methylene blue test, but tubes are held at 37°C. for only one hour and the colour of the resazurin-milk mixture is then compared with tinted glass discs in a comparator. This test is interpreted as follows:

Disc number	Colour	Bacterial quality
6	blue	excellent
5	lilac	very good
4	mauve	good
3	pink-mauve	fair
2	mauve-pink	poor
1	pink	bad
0	white	very bad

As a platform rejection test for detecting milk of poor keeping quality a modification of the above test has been adopted by the Ministry of Agriculture and Fisheries, United Kingdom. In this test, 10 millilitres of milk are mixed with one millilitre of resazurin reagent and incubated at 37°C. for 10 minutes after which the colour is graded by the coloured disc comparator. When the colour is intermediate between two disc values it is recorded as a half value. The following standards are accepted for judging market milk by this test (70 and 71):

Disc reading	Category	Action taken
4 or higher	A	Accepted
3½ to 1	B	Salvaged if possible, otherwise rejected
½ to 0	C	Rejected

Another modification of the resazurin test, recognised by the Ministry of Agriculture and Fisheries, United Kingdom, is the resazurin-rennet test. This modification is of use to cheese makers in detecting milk which form s an abnormal coagulum

with rennet. In this case, sufficient rennet (0·1 to 0·2 per cent commercial rennet solution) is added to the resazurin solution to clot normal milk in 30 to 60 minutes. Ten millilitres of milk and one millilitre of the resazurin-rennet solution are mixed and incubated at 37°C. The sample is examined at 15-minute intervals for coagulation and at 30-minute intervals for colour changes up to two hours. Very dirty milk will clot within one hour because of the acid formed by bacteria; mastitis milk clots slowly because of its alkalinity and different protein composition. If the milk is not clotted within 1½ hours, the mastitis infection is serious (23 and 111).

The strength of the methylene blue solution that is used is sufficient to give a concentration of one part of dye to 300,000 parts of milk. If resazurin is used, a 0·005 per cent aqueous solution is added to milk at the rate of one millilitre of the solution to 10 millilitres of milk. Colours observed in the resazurin-milk mixture, which is incubated in the dark at 37°C., are a slate blue at first, followed during reduction, by violet, pink and white in that order.

The Bacterial Plate Count

The bacterial plate count is carried out by mixing known quantities of a milk sample, obtained by dilution in the manner explained below, with a liquefiable solid medium. The medium usually employed is nutrient agar containing 1·5 per cent agar, 0·3 per cent beef extract, 0·5 per cent tryptone, 0·1 per cent glucose and 1·0 per cent skim milk, in distilled water (31). The measured portion of the sample is mixed in a petri dish with the medium while it is still liquid. This is then allowed to solidify when it is inverted and incubated at 32° or 37°C. for 48 hours. Two or possibly three dilutions should be plated in duplicate so that one set of plates will show between 30 and 300 bacterial colonies per plate. The number of colonies on each of this particular set of plates multiplied by the dilution they represent will give the number of bacteria in one millilitre of the milk concerned. This is the standard way of expressing the bacterial count when this method of counting is employed. All equipment must be previously sterilized under steam pressure to make sure it is not a source of contamination which would influence the results of the test.

The quantity of milk employed for the bacterial plate count is commonly a small fraction of one millilitre. A count of one million bacteria would require a dilution of 1 to 10 thousand since fewer than 300 colonies are necessary on a single plate. The preparation of samples by the measuring of such extremely small quantities of milk is simple if the dilution technique is employed using quantities of sterile distilled water. Two methods of dilution to give extremely small fractions of one millilitre of milk for a single test are indicated below.

Dilution of the Milk Sample for the Bacterial Plate Count

Method I

Dilution number	Mixture		Amount of mixture to use	Dilution in decimals	in fractions
A	Milk only		1 ml.	1·0	1/1
B	9 ml. water	1 ml. milk	1 ml.	0·1	1/10
C	9 ml. water	1 ml. B	1 ml.	0·01	1/100
D	9 ml. water	1 ml. C	1 ml.	0·001	1/1000
E	9 ml. water	1 ml. D	1 ml.	0·0001	1/10000
F	9 ml. water	1 ml. E	1 ml.	0·00001	1/100000

Method II

Dilution number	Mixture	Amount of mixture to use	Dilution in decimals	in fractions
A	Milk only	1·0 ml.	1·0	1/1
B	Milk only	0·1 ml.	0·1	1/10
C	99 ml. water 1 ml. milk	1·0 ml.	1·01	1/100
D	,,	0·1 ml.	0·001	1/1000
E	99 ml. water 1 ml. C	1·0 ml.	0·0001	1/10000
F	,,	0·1 ml.	0·00001	1/100000

The Breed Count

The Breed count is a method by which the number of bacteria in a sample of milk is counted directly by use of the microscope. This method is sometimes known, therefore, as the direct microscopic method. The Breed method involves the use of 0·01 millilitre of milk which is spread over an area of

one square centimetre on a glass slide. The slide is then placed in a level position to allow the sample of milk to flow evenly over the area. In this position it is allowed to dry. The fat is then removed and the smear is fixed and stained by the use of the Newman-Lambert stain or by staining with methylene blue after removing the fat in xylol and fixing in alcohol. The slide is then observed under a standardized microscope. The bacteria found in 60 fields must be counted, the average number per field is then multiplied by the necessary factor to give the bacterial count per millilitre of the milk.

A microscope is standardized by measuring the diameter of its field with the draw tube in a fixed position. The area of the field can thereby be determined. From this, together with the thickness of the milk film on the slide, uniformly 0·01 centimetre if prepared as outlined above, the fraction of one millilitre of milk observed in each field may be determined. The factor, referred to above, is the number of fields per millilitre. The average count per field multiplied by this factor gives the number of bacteria in one millilitre of the milk.

The Breed count is in reality an individual cell count, whereas the bacterial plate count is a source or clump count. In the latter case one colony results from each clump of bacteria in the solid medium, regardless of the number of cells in a clump. For this reason the ratio between the plate count and the direct microscopic count on the same milk will be found to average about 1:4 (31).

CHAPTER VII

DAIRY ENGINEERING

The broader interpretation of the term dairying which has been used throughout this text includes not only the processing and distribution of milk, but its production and the production of as large a proportion as possible of the feed consumed by the dairy herd. In this sense, dairy engineering includes the engineering aspects not only of the dairy and the cattle yard but also those of a farm producing fodder and concentrate feeds for the milking herd. Since the general engineering considerations of a farm are usually included under discussions of agricultural engineering, even though the farms may have characteristics of a more specialized type of operation, such as a dairy farm, this aspect of dairy engineering will not be considered here. Attention will be confined to problems of the management and maintenance of a dairy herd and the operation of a dairy or creamery.

India's climate is very different from that of most of the principal dairy countries of the world. Literature is available recommending structures and types of construction of dairy buildings for countries differing from ours. The information that has become available so far about the construction of buildings to meet conditions prevailing in India is scarce. Any recommendations, therefore, must be based largely upon information which is not fully applicable, or they must be original and not the product of adequate experience under our conditions.

Buildings which are required in the cattle yard are the milking barn, sheds, feed store, calving pens or stalls, silos and milk house.

Milking Barns

Milking barns should be constructed of strong and durable materials, principally bricks and concrete. The floor should be strongly built and well finished. Good quality

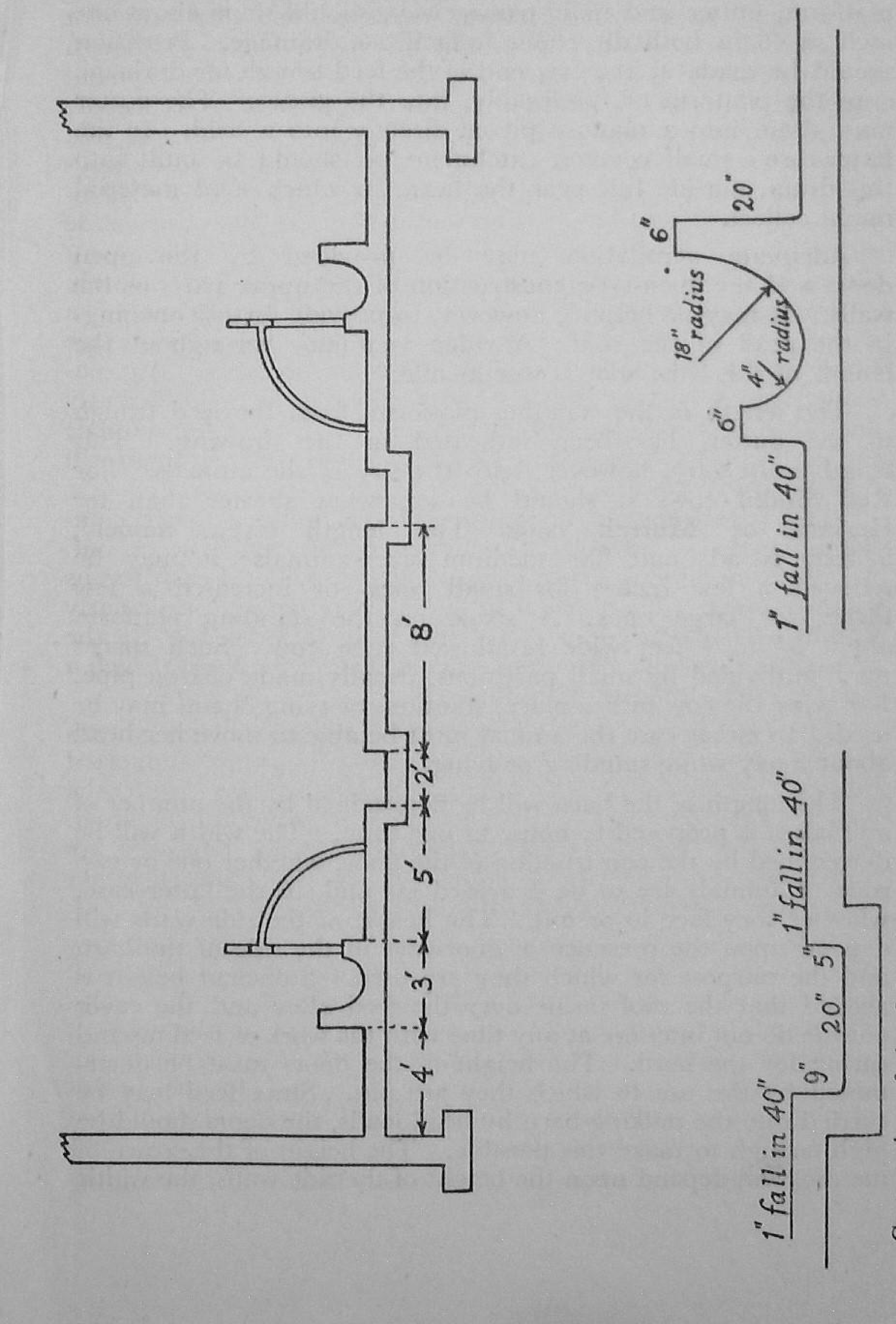
bricks laid with strong cement concrete may be sufficient for such floors. Better floors can be made, however, though not necessarily at a lower cost, by use of rich cement concrete only. The finish for such a floor should be well made in order that the floor will withstand years of continuous use. This surface must at the same time be so finished that the animals will not slip on it, for in slipping they may injure themselves, possibly seriously. The surface of the floors, if made of bricks and concrete, may be left rough just as it is when completed, that is it should not be ground down to make it smooth. A concrete floor should not be smoothed by means of a trowel, but by means of a board which will leave the surface rather rough yet plane so that it will drain properly. Alternatively, grooves may be cut into this surface sufficiently deep that they will prevent slipping on the part of the animal; the pattern of such grooves must be such that water in them will readily drain away.

The arrangements of animals in a milking barn commonly involves two rows of animals facing either in or out. There are numerous advantages in each system and each has its disadvantages. There seems to be some preference, particularly in milking barns as compared to structures for other use, for the animals to face out. A cross-sectional plan of the floor of such a barn is given opposite (43 and 30).

The roof should be well supported and thoroughly waterproof. Heavy tiles are best, provided they are supported by steel beams. Wooden beams frequently sag from the weight of the tiles and may be attacked by white ants or fungi. A tiled roof can be easily repaired. Where monkeys are numerous, however, it is well to lay the tiles together with cement to prevent damage from these pests.

The walls must be strongly constructed in order that they will stand for many years and will support the heavy roof. Bricks layed in cement are excellent material for the walls. The upper part of the walls, say above four feet, may be made of open-type construction to facilitate ventilation. Such an arrangement is not likely to prove injurious to the health of the milking animals by admitting cold wind and rain from which they should be protected.

The floors, including the feed alley, feed trough, standing



Cross-section of the floor of a milking barn with two rows of cows facing out. Enlarged sketches of the gutter and the feed trough are shown and dimensions are given.

platform, gutter and main passageway, should slope about one inch in 40 in both directions to facilitate drainage. Provision should be made at the low end of the feed trough for drainage onto the platform or, preferably, into the gutter. The gutter must drain into a manure pit or directly into a field. In the latter case a small covered catchment pit should be built into this drain, outside but near the barn, in which solid material might collect.

Adequate ventilation may be provided by the open doors and the open-type construction of the upper parts of the walls. It may be helpful, however, to provide further openings in the peak of the roof. A ridge ventilator throughout the length of the barn roof is worthwhile.

The length of the standing platform, from the feed trough to the gutter, has been indicated in the drawing. This length must vary, however, with the size of the animals. For Red Sindhi cows it should be somewhat shorter than for Hariana or Murrah cows. The length given, namely, 5 feet, is adequate for medium size animals; it may be reduced a few inches for small ones, or increased a few inches for large ones. A space on the standing platform about 3½ to 4 feet wide is allowed each cow. Such spaces may be divided by small partitions, usually made of iron pipe. For tying the cow in her place, stantions or tying chains may be used. In either case the animal must be able to move her head about freely while standing or lying.

The length of the barn will be determined by the number of animals it is proposed to house at one time. The width will be determined by the construction of the floor, whether one or two rows of animals are to be provided for and, in the latter case, whether they face in or out. The height of the side walls will depend upon the presence of doorways in the side of the barn and the purpose for which they are used. Sufficient height is needed that the roof inside over the feed alley and the eaves outside do not interfere at any time with the work of feeding and caring for the herd. The height of the doors must be determined by the use to which they are put. Since feed may be carried into the milking barn by head loads, the doors should be high enough to make this possible. The height of the crown of the roof will depend upon the height of the side walls, the width

of the barn and the slope of the roof. The roof must slope sufficiently to provide for proper drainage during the heaviest rains.

The walls may, for purposes of economy, be constructed of bricks layed in mud. Should wood be used in the roof, however, mud will not prove satisfactory in the walls for white ants readily work up through this material and attack that wood. Furthermore, such walls must be pointed or plastered with cement to prevent the mud being washed out of the walls during the monsoon.

The location of the milking barn will depend upon several factors, of which the location of other buildings, protection from the sun and winds and the level of the ground are some of the most important.

Milk House

To make the production of clean and safe milk possible a small milk house constructed very near, yet outside the milking barn will be required. The milk house should be located outside the milking barn in the direction from which the prevailing winds blow so that dust, dirt and the odours from the milking barn are not carried directly to it by the wind. The land about this building should slope away from it, as well as away from the milking barn, to prevent any possible accumulation of water and barn effluent near these buildings.

The milk house need not be large. It must provide only for the receiving of the milk at the milking time from the barn as each animal is milked, with some space for the storage of a few cans. If the dairy is some distance away, facilities may have to be provided for the washing and sterilization of pails and cans in the milk house. Otherwise this may be done at the dairy or creamery. A milk house about 6 feet wide by 8 feet long, possibly 8 feet high, will be sufficient for a milking herd of up to 200 cows.

The structure should be strongly made. The windows and doors should be tightly fitted and screened to keep out the flies and as much dust from the air as possible. Windows should be of such a size and so placed that they admit light and fresh air to all parts of the interior of the milk house without admitting direct sun light during the hot summer months.

Calving Stalls

Special pens or stalls should be provided for use as calving stalls. These may be constructed in the milking barn, but preferably in a separate shed, possibly in the paddocks. They should be about 10 feet square with a solid floor which is well drained. Adequate ventilation is essential. The construction should be such that the stalls can easily be kept scrupulously clean at all times. Such pens should be so located that they are fully accessible to those responsible for the supervision of the cows at parturition.

Feed Store and Silos

A milk cow will consume a large quantity of feed during a year. Although some feed materials are obtainable through the year, they can usually be obtained at a lower price in certain seasons. Some materials are available only seasonally. To make feeds available regularly and to make it possible to obtain some of them most economically, storage space for both fodder and grain feeds is required. Fodder is frequently stored in a dry condition, but storage in a succulent condition as silage is preferable; losses can be minimized and the food value of the fresh fodder can be almost completely retained by ensiling green mature fodders.

Feed Store

Enemies of feed grains are rats, mice, birds, insects, moulds and moisture. Grains should be stored only when they are thoroughly dry, in a room in which they may be kept dry and into which rats, mice, birds and insects may enter only with difficulty, if at all. Rats, mice and birds may be kept out of such grains by tight fitting doors and screened windows; the doors, if made of wood, should be fitted with metal plates on their lower portions to prevent rats and mice from gnawing their way through them. It is difficult to keep weevils out of grains, except by fumigation. White ants may be kept out of such materials almost entirely by properly constructing the walls and floors of the storage rooms. Where the construction is of bricks and/or cement concrete white ants will be excluded, *provided* the construction is tight so that these insects cannot work their way through by following small holes and cracks.

Feed store rooms may be included in the milking barn or a separate building may be used. In the former case it is essential that these rooms be sufficiently separated from that in which the milking is done that the dust and debris inevitably associated with the handling of the grain does not gain ready entrance into the barn where it might be a source of contamination of the milk or milk utensils. In this respect, a separate feed store is preferable, although this may involve more labour in the transport of the grain to the milking barn at feeding time. Feed stores should be so located that loads of feed can be unloaded directly into them.

Silos

Silos may be built above or below the ground. Those below the ground level are of two kinds, the trench silo and the pit silo. The former, as the name implies, is a long trench the dimensions of which vary with its capacity; the latter is like a huge cylinder dug into the ground. The trench silo requires a greater land area for a given capacity than the pit type, but the level of the water table beneath the ground and the nature of the soil may limit the depth to which the pit may be dug. Where the land is slightly rolling the trench silo can be dug in the side of and at right angles to the slope of a hill so that one end opens at ground level. This facilitates drainage. Losses may be greater in the trench than in the pit silo because of the greater area of the top surface which must be protected from the air. On the other hand, the removal of the silage from the trench is less difficult than from the pit. Excellent silage, however, may be made in either type.

The underground silos may or may not be lined with masonry, usually bricks. The trench silo is less often lined than the pit type for the side walls of the former may easily be sloped throughout their smaller height to prevent their caving in when the silo is empty. The nature of the soil into which the cylindrical pit silo is dug may make it necessary that some provisions be made to prevent caving of the side walls. This can best be provided by lining the pit with bricks. They need not be layed in cement, mud will serve fairly well. They must, however, be layed in an archlike manner around the curved sides of the pit so that any

pressure from the outside will be distributed throughout the pit lining and not bear entirely upon a small portion of it.

Silos constructed above the ground may be built of masonry or other materials. Bricks, tiles, wood or concrete staves, or cement concrete may be used. Other silos above the ground are made of woven wire, snow fence or wood panels lined with heavy paper, or the fodder may itself serve as the tilo in that fodder may be stacked above ground with no protections other than that afforded by the outer layers of the stack. Losses due to spoilage depend upon the degree of protection from the air which encourages profuse mould growth. Losses are greatest in the surface layers of the silage in all types of silos, with the possible exception of those of non-masonry construction above the ground. In these there is additional loss due to spoilage on the sides, particularly the stack type in which losses of up to 25 per cent may occur.

The trench and pit silos have been found to be more satisfactory in India than masonry silos built above ground. Two reasons may be given for this, namely, improper construction of the masonry type and the low cost of the trench or pit silos. These latter are within the realm of economic possibility for most village farmers, for providing silage for their milk or their work cattle, and might well be recommended in perference to the others.

The weight of silage per cubic foot will vary with the height to which it is stacked. For shallow silos, say of less than 10 feet, the silage will average about 32 to 35 pounds to the cubic foot after being allowed to settle. This weight will increase gradually with increases in the height to which the silage is piled until it reaches an average of about 39 pounds or so when around 30 feet high. The weight per cubic foot at these depths will be about 38 pounds at 10 feet and 43 pounds at 30 feet (30).

The dimensions of a silo are determined by the size of the herd they are designed to care for and the length of time silage is to be provided. The cross-sectional area of a silo is determined by the size of the herd, for the entire surface to a depth of several inches should be used daily to prevent excessive spoilage; the length of the longitudinal dimension will be determined by the length or the feeding season. The ground water level will limit the depth of a pit silo. If a greater

depth is required than the ground water level will permit, two or more silos may be built.

Sheds

Satisfactory management of the dairy herd requires the use of paddocks or corrals in which the milking animals may be confined at times near the barns, whether grazing land is available or not. Young stock are commonly confined to such areas until they enter the milking herd. To protect the animals from the weather in such paddocks some type of shed should be provided. Protection from the sun, rain and wind is necessary if the health of the animals is to be maintained. Large shade trees will provide protection from the sun, but not from the wind and rain. A good shed, properly constructed, will give the necessary additional protection, but should not displace good shade trees.

The simplest construction of sheds for the paddocks involves the use of wooden poles which support a thatched roof and thatched side walls. White ants and other destructive agents, possibly the animals themselves, soon make extensive repairs necessary on this type of shed. For this reason it is very questionable whether it is the most economical type, although it may involve the minimum of capital expense.

Other materials which may be used in the construction of such sheds are bricks and cement concrete for the floor and walls and tiles or iron or asbestos sheets for the roof. The roof may be supported on wooden or iron beams. A shed built from such materials will be a somewhat more expensive structure than that made of thatch, but it will be far more durable. In fact, the more expensive shed is likely to prove economical because of the much lower repair costs.

A good shed may be built of bricks and cement. The floor should drain well, sloping at least one inch in 40; the walls should be built on three sides only and of open-type construction above 4 feet. Tiles supported by iron beams make an excellent roof which offers more protection from the sun than iron sheets, possibly more than asbestos sheets. The size will depend upon the size and number of animals to be accommodated.

The shed should be located so that drainage is away from the shed on as many sides as possible. In no case should the sur-

rounding land drain toward the shed from more than one direction. The location of the paddock will determine the location of the shed, in the first instance.

Fences

Two common methods of confining animals to a designated area are in use in India. In the first case men, women or children may herd the animals ; in the second, fences may be used.

Miscellaneous Fences

Fences may be made of a variety of different materials. Rows of thorny bushes or cactuses are sometimes used. Brick fences are walls made of bricks layed in mud or cement; they may be of solid or open-type construction or both. Those made of stones are solid with the stones layed loosely or with mud or cement. Wood fences are uncommon because of the danger of white ants. The three types of wood fences are the panel, picket and rail. Iron fences are commonly ornamental, hence usually sorround gardens or yards of private estates or city parks. A type of iron picket fence may be seen along railway station platforms.

Wire Fences

There are three types of wire fences. Firstly, the wire strand fence consisting of two or more strands of plain or barbed wire stretched tightly between poles of wood, iron, stone or cement concrete. Plain wire is not so satisfactory for dairy animals as barbed wire which has long sharp barbs fixed at regular intervals to a double twisted wire. The number of wires and their spacing depends largely upon the type of fence and the kind and size of animals to be confined. Posts may be one rod (16½ feet) apart, frequently more. The closer the posts and the tighter the wire the more serviceable the fence, in general, for confining animals.

A second type of wire fence is that made with woven wire. This wire consists of several parallel strands of plain wire which are tied together with cross wires. The over-all width of this wire and the interwire spaces vary considerably with the purpose for which it is intended. The height of the fence is not limited to the width of the woven wire, however,

for additional barbed wires may be used above or below the woven wire to increase its effectiveness. This is a comparatively expensive type of fence. More posts are needed to support it and the corner and brace posts which maintain its tension must be more numerous and stronger than in the case of the wire strand fence.

The third type of wire fence is the electric fence. This usually consists of a single strand of wire, preferably barbed wire for cattle, stretched tightly over supporting posts. This wire is electrified. The current that is required is sufficient to give the animals a noticeable shock when they contact the wire and ground the current through their bodies, yet insufficient to make it dangerous to the animals, to workmen or to visitors. The posts should be spaced about a rod apart and the wire fixed to them by means of an insulator. The wire should be between 25 and 30 inches above the ground for mature animals; 20 to 25 inches for calves and young stock. Gates are provided with a hook and loop connection of the two ends of the wire at the opening. The gate wire is fitted with an insulated grip or handle with which to open and close the gate. This type of fence has been used successfully for several years at the Allahabad Agricultural Institute for zebus; it is, however, not so satisfactory for buffaloes. The current used for that installation, which, with two wires appropriately spaced instead of one, is also used for goats and pigs, is 600 volts and 9 milliapheres. A slightly higher voltage, possibly up to 750 volts, may be used, but an ampherage of 11 milliapheres or higher is considered dangerous.

Feed Grinders and Chaffers

The feeding of whole grain or of unchaffed fodder is definitely uneconomical. The dairy farm must, therefore, be equipped with grinders or chaff cutters by which concentrates or grains may be crushed and fodder chaffed. The capacity of such machines will depend primarily upon the amount of feed or fodder to be processed.

Grinders or chaffers may be operated by hand or by mechanical power; the latter is preferred. Where electricity is available it is indeed more convenient than power provided by any other means. These machines require con-

siderable care. They usually operate at a high speed, unless hand operated. In any case it is essential that they be adequately lubricated and, in the case of chaff cutters, the knives and cutting bars must be properly aligned and adjusted. Care must be taken to assure there being no stones or pieces of metal in the grain or fodder for such things may cause considerable damage to the machine or to the animal ingesting them.

The Milk Plant or Creamery

The operation of any plant in which milk and milk products are handled involves considerations of sanitation, convenience and economy. Rooms in which fuel, supplies, dirty cans and bottles and raw products are handled should be separated from those in which processing is carried out. Steam or hot water and refrigeration should be made available as near as possible to where heating, cooling and washing operations take place. Milk or other raw materials should be received as near as possible to where they are to be processed. The movement of materials or equipment during the processing of milk or milk products should be reduced at every opportunity. Greater convenience throughout the plant should be sought continuously in order to reduce the labour required and to make operations simple and less tedious.

Factors governing the selection of the site of a dairy or creamery building are listed in Chapter XIII. The size of the dairy building must be determined by the quantity of milk or milk products and the number of different products to be handled. In any case the building should be of adequate size, well constructed and well ventilated. The plant should not be larger than necessary, however, for that unnecessarily increases overhead expense and labour.

The Arrangement of the Rooms

The arrangement of rooms in the dairy should take into account the use to which different rooms will be put. The boiler rooms, for example, will involve the handling of coal or other fuel, the disposal of ashes from the fire box and the disposal of smoke. Considerable dirt and dust, therefore, will have to be contended with. Such a room must not be so located that the dust associated with it might be a source of contamina-

tion either of utensils, equipment, milk or of milk products. The steam or hot water provided by the boiler, however, must be as readily available to the wash room and to the pasteurizer or other equipment requiring these materials as is possible. The location of the boiler room, therefore, will be determined both by the need for it being somewhat removed from the site of some operations in the creamery and by the need for it being fairly close to others.

The compressor is a machine with which there is a certain amount of dirt, particularly oil, associated. It is not desirable that the room in which the compressor is located be open to rooms in which milk or milk products are handled or utensils stored. Furthermore, the condenser operates most efficiently with water or air that is as cold as possible, hence it may be inconvenient to place the compressor and the boiler in the same room. Where the compressor and boiler are to be located in the same room it may be well to have the condenser located elsewhere. Whether water or air cooled it should not be located in the boiler room nor should the pipe feeding a water cooled condenser pass through the boiler room immediately ahead of the condenser.

The wash room should be located close to both the receiving platform and the boiler room, yet should not open directly into the main plant room where milk is handled or processed. Considerable dust, dirt or, in the rainy season, mud is always associated with the receiving platform as it is there that milk is received from the producers. It is not good practice for cans in which milk is received from outside the plant to be carried through any part of the plant before they have been thoroughly washed inside and out. It is essential, for this reason, that the room in which they are to be washed open immediately off the receiving room or platform. This wash room must be close to the boiler room in order to reduce losses of heat that will inevitably occur in the transportation of hot water or steam through pipes from one place to another. Rather effective insulation of these pipes is possible, but it is impossible to eliminate such losses completely. It is not advisable, however, for the boiler room and the wash room to be continuous, for cleaned cans and other utensils are usually stored in the wash room. They must not be exposed to possible sources of contamination, such as coal dust and ashes.

There is a certain amount of dust and debris inevitably associated with stocks of supplies. It is desirable, however, that the room in which such materials are stored be kept as clean as possible in order that the supplies be a source of a minimum of contamination in the product with which they will be used. It is not well to use the boiler room as a supply store room nor for the store room to open directly off the boiler room. Furthermore, it is unwise for the stock room to open directly off the main plant room since it may prove a source of dust and dirt with which milk and milk product as well as equipment may become contaminated.

It is especially essential that the room in which fuel is stored, whether it be coal, wood or oil, does not open directly into the wash room, the supply store room or the main plant room. It is possible for the fuel store room to open into the boiler room for that fuel must be immediately available there. The boiler room might in turn open into a small hallway leading from the main plant room or preferably from the wash room to the outside of the building. The supply store room may open into this hallway, provided its door is always kept closed and every possible effort is made to keep the hallway as clean as possible as well as to be certain that the boiler room door is tightly closed whenever fuel is being handled.

The receiving room or platform should be largely closed off from the main room with the milk being passed from one to the other through a pipe only. The dirt that is found in the receiving room may be prevented, thereby, from entering the main plant room.

So long as the necessary precautions are taken to avoid contamination from external sources, particularly from other parts of the building, the main plant room may be constructed in any location within the building. It is preferable, however, that it be so located that the prevailing winds do not carry dust and dirt from other parts of the building or from nearby streets or buildings into this room through windows or ventilators. Furthermore, it should be so constructed that it gets plenty of light, but not direct sun light, throughout the room.

It may be advisable where it is possible to do so to locate the fuel store rooms, the boiler room and supply store room in the basement beneath the remaining portion of the building unless the plant is a very large one when they may be located in a

building separate from the milk plant. Proper ventilation of such rooms in a climate like India's, however, is very difficult.

Floors

The floor of the receiving platform or room, the cold storage rooms, the wash room and the main plant room must be of very strong, durable waterproof construction. Various types of materials may be used, some of which, however, are rather expensive. One of the best materials, but probably the most expensive, is a high grade tile laid in very rich cement and allowed to harden thoroughly before it is used. Such a floor is extremely durable, being liable to very little damage under ordinary use, and thoroughly water tight if properly constructed.

The use of good cement concrete is more practicable for most purposes. Such floors should have a good concrete base which is surfaced with a layer, one-half to one inch in thickness, of very rich cement concrete, preferably made by the use of water-proof cement. Such a floor should be well cured before it is used, otherwise it is liable to rapid deterioration. A floor that is constructed in this manner may be reinforced at certain places, such as in doorways and near certain types of equipment where traffic is very considerable, by imbedding iron gratings into the floor as it is layed. These gratings may be made of iron strips, about one-quarter of an inch thick by one inch wide, so fixed together as to form an open net-like grating with the strap iron on edge. This grating is then imbedded level with the floor surface. The life of a floor, particularly in areas where it is used considerably, can be increased many times by the use of such reinforcement.

Floor Drainage—Floors should slope sufficiently that rapid drainage is possible. There are occasions in most milk plants when great volumes of water must be dumped at one time. The floor should be sloped in such a manner that this water will drain off rapidly. Floors should be sloped one-quarter of an inch to the foot (34). The rapidity with which water will drain from the creamery floor, apart from its slope and the uniformity of the slope, depend upon the type of drains. The best drain is probably one which extends the full length of the room down

the centre of the floor. The capacity of such a drain is usually greater than that of other types so that it is one of the most effective for rapidly removing excess water. Whatever the type of drain, it should be equipped with a water trap which will prevent gases and fumes passing from the sewage pipe back into the building. The ideal arrangement is to locate the trap outside the building by extending the drain to the outside. All drains should be covered with perforated iron plates which are flush with the floor. This prevents debris from entering and clogging the drains and prevents injuries to the workmen who are likely to slip into uncovered drains sometimes. The bottom of the drain channel should be rounded to facilitate proper cleaning.

Walls

The walls of the milk plant should be made of strong and durable materials with their inside surface, at least for the first four feet or so, waterproof. This may be done by plastering them with a coat of waterproof cement, by the use of a special grade of tile with which to face that portion of the wall or by use of glazed bricks. It is even more desirable, where possible, to make the whole inside surface of the side walls waterproof. Frequent washing of the walls is essential to proper plant sanitation; the construction suggested makes this feasible.

Ventilation

The plant should be so constructed that adequate ventilation is possible. Windows, if they are large enough and well placed, and doors will allow considerable air circulation in the lower part of the building, but must be supplemented by openings near the ceiling to remove warm moist air that will accumulate above them and may become stagnant. It is suggested, therefore, that an opening of at least 18 inches be made immediately next to the roof and that the roof extend beyond this opening on the outside sufficiently to protect it. Any air entering the windows and doors may find exit through other openings, including this one near the ceiling, thereby effecting satisfactory ventilation of the entire plant. If the roof is flat this opening will be made in the side wall; if it is peaked, it will be made in the peak of the roof. *All openings must be screened* to exclude flies, birds, monkeys and other pests.

Washroom Equipment

The equipment in the washroom should consist of a two or three compartment washing tank; slat-type shelves or racks on which to store the clean utensils; provision for sterilization, which, if steam is used, consists of an autoclave or retort, a steam chest or a steam jet or, if chlorine sterilization is used, an extra compartment in the washing tank in which the chlorine solution may be prepared. Large milk plants may find it economical to employ mechanical bottle or can washers.

The washing tank may be made of sheet iron or reinforced brick and cement. Sheet iron has certain advantages, although the reinforced brick and cement construction costs less to install and, though they may be necessary more often than for the iron tank, repairs usually cost very little and can be made by most any skilled bricklayer. Repairs on the iron tank, on the other hand, may require special welding or other equipment not readily available. Each tank compartment should be sufficiently large that a 10-gallon can may be completely immersed in it during washing.

The best racks are constructed of several bars of one-half or three-quarter inch iron pipe, preferably galvanized. Such material is expensive, but if available it is preferred to wood because it is easily cleaned and is very durable.

An autoclave is a rather expensive piece of apparatus which is not commonly used. It is a steel chamber of sufficient strength to withstand internal steam pressures of 60 to 100 pounds per square inch, although 15 pounds pressure is usually used. The extra strength is needed to avoid accidents where excessive steam pressure is inadvertently permitted. The steam chest may be made only of wood or of wood lined with galvanized or sheet iron. It must be large enough to hold several cans, pails and cases of bottles. The door must be such that it can be tightly closed to confine the steam to the interior of the chest. The bottom should slope to one side or to one corner where a drain is provided to remove water which condenses from the steam. Either the autoclave or the steam chest may be built in the wall between the wash room and an airing and drying room, or the main plant room and have two doors, one opening into each room. Utensils may then be placed in the unit on the wash room side and removed on the other side for

convenience. A jet consists of a small diameter, short pipe protruding through a small platform at least 15 inches square. Steam is admitted through the jet by an ordinary hand valve; a valve operated by a hand lever may be used.

Numerous types of mechanical can and bottle washers are available in varying capacities. Where such equipment is desired the deatils of the capacity, type and mode of operation may be obtained from dairy equipment manufacturing and supply companies.

Steam Boilers

Steam boilers are of two types, the water tube and the flue tube. In the water tube boiler, water, from which steam is to be produced, is confined in pipes or tubes which are exposed on all sides to the fire. In the flue tube boiler, the heat and fumes from the fire pass through tubes which are surrounded by water. The boiler of small capacity that is ordinarily used in dairies is of the flue tube type. That used on railway locomotives is a fine tube boiler. The water tube boiler is usually used for larger installations, such as for operating electric generators driven by steam turbines.

The boiler may be a vertical boiler with the fire box at the bottom, or a horizontal boiler with the fire box at one end. In the former case the heat passes upward from the fire, through the tubes, and out through the smoke stack. In the latter case the fire and fumes pass from the fire box through the flue tubes, to the opposite end of the boiler and then upward through the smoke stack. Certain kinds of horizontal boilers are constructed so that the fire and fumes pass from the fire box beneath the battery of flue tubes to the opposite end of the boiler, then back through the tubes to enter the smoke stack immediately above but in a separate chamber from the fire box. Boilers used in a dairy should be strong enough to withstand pressures well over 100 pounds to the square inch. They should always be equipped with a safety valve which will prevent pressures exceeding a certain predetermined figure and should be sufficiently large to provide a continuous supply of steam at pressure up to 60 pounds. The size of the business and the type of operations carried out largely determine the pressure and the volume of steam required in a creamery.

The capacity of boilers is usually given in horsepower. This refers either to the heating surface area or quantity of water at 212°F. converted into steam at atmospheric pressure (8). The latter method is more common.

Any steam boiler may be used for providing hot water either by operating it so that the water is heated only to boiling temperature, or by using the steam for heating water. Where hot water is used and steam is not required, however, it is not necessary to have the more expensive boiler designed to withstand high steam pressures. A low pressure boiler may be satisfactory. A satisfactory type for this purpose is the water jacketed boiler. This consists of an outer shell and an inner shell between which the water is admitted. The fire is placed inside the inner shell so that as the fumes and flame pass through the length of the boiler heat may be absorbed on all sides by the water. Where the feed tap line enters directly into such a boiler, pressures will not exceed the tap pressure, for as the pressure in the boiler builds up sufficiently the flow of water through the feed line will be reversed. Hot water may be stored in a separate storage tank, or it may be drawn directly from the boiler as it is used. The advantage of the storage tank is that greater quantities of water may be made available at that time when a considerable demand for hot water exists, as commonly happens several times daily in most creameries.

Pasteurizers

Different types of equipment may be used for the pasteurization of milk or cream by the different exposures listed in Chapter VIII.

Pasteurizers for the Vat, Batch or Holding Method

Three kinds of vat pasteurizers are widely used in which the heating or cooling water is contained in the interjacket space. The *water jacketed* unit is so called because the space between the jacket and the insert is filled with water which is heated or cooled according to the change of temperature desired. In the *spray jacketed* unit the water is forced through a perforated pipe located near the top of and within the interjacket space. The perforations are so arranged that the water is directed against the outside surface of the insert down which it flows by gravity.

As this water drains off at the bottom it is returned to the supply reservoir by the circulating pump. These vats are equipped with agitators of either the paddle or the propellor type.

Coil pasteurizers are of two kinds. These are the horizontal and the vertical coil pasteurizers, depending upon the position of the coil. In either case the interjacket space is filled with an insulating material to prevent the atmospheric temperatures from interfering with the heat treatment given to the contents of the vat. A large coil fixed inside the vat serves as the agitator as well as the heating and cooling unit. While the coil rotates, water is circulated through it from a supply reservoir. The vat should be filled sufficiently to cover the coil, particularly in the horizontal coil unit, during heating. Should part of the coil be uncovered during operation there is considerable danger of the milk which clings to the exposed portion of the coil being over-heated. This is likely to cause the appearance of a strong cooked flavour in the milk as well as the accumulation of milk stone on the coil surface. The difficulty of cleaning the coil is one of the principal disadvantages in this type of pasteurizer. The accumulation of milk stone on the coil aggravates this difficulty and interferes with the passage of heat through the coil.

Pasteurizers for the High-Temperature Short-time and Flash Methods

Three general types of pasteurizers are in use for the pasteurization of milk or cream by the high-temperature short-time, also called hot-short, and flash methods. Either of the two methods involves the heating of the milk to a rather high temperature at which it is held for a very short time and then rapidly cooled. Either might be rightly called a hot-short method, but they are distinguished by the use of different terms because of their effect on the physical properties of the product, especially the creaming property of market milk.

Plate heaters consist of a series of flat grooved plates so constructed and arranged that the milk is directed through alternate interplate spaces, whereas the heating water is passed counter-current to the milk through the remaining spaces. The capacity of such heaters depends upon the quantity of hot water and its temperature, the temperature of the milk before and after heating, the size of the plates and the rate

the milk flows through the unit. Heating is very rapid as the milk or cream must pass in a thin film between the heated plates. The temperature to which it is heated, as is explained in Chapter VIII, is sufficient that the time required to pass through the heater and to the cooler brings about that degree of bacterial destruction required. Holding vats or tanks are unnecessary, which is also true of the heaters described below.

Tubular heaters are of several types. In each case one tube, through which milk is passed, is jacketed by a second and larger one; the water passes through the outer tube counter-current to the milk. The milk tubes may be jacketed singly, in pairs or in groups of three or four. A special kind of heater of this type, known as a Stassaniser, consists of a large cylindrical drum containing four double tubes. The space between the inner and outer tube is only one to one and one-quarter millimetres wide. The milk passes through this space, while the heating water passes through the interior of the inner tube and surrounds the outer one.

Drum heaters are generally used for the flash method of pasteurization while the plate and tubular heaters are used more often for the hot-short method. This unit consist of a double metal drum. A high speed agitator with scrapers is fitted in the inner drum into which the cream is admitted. The heating medium, which in this case is steam, is admitted into the space between the two drums. Milk is forced through this unit at a high speed, depending upon the temperature increase required and the steam supply. The agitator and scraper assembly is designed to prevent any portion of the milk or cream staying in contact with the heating wall more than an instant. This facilitates rapid heat exchange, yet prevents scorching or burning.

A flash pasteurizer of the drum type generally consists of two-drum units and a regenerator. The cream is heated to 150°F. or so in the first drum unit and then passes through the regenerator where it is further heated by the return cream from the second drum unit. In the second drum unit the temperature is further increased to at least 185°F. The return cream flows over the regenerator before going to the cooler. Pasteurization by the Stassaniser is also accomplished in two steps utilizing a regenerator between to increase the economy of heat

utilization. Pasteurizers of the plate or tubular heater type, except for the Stassaniser, consist of one heating unit without the regenerator.

The most recent development in *vacuum pasteurizers* is the *Vacreator* invented by H. Lamont Murray of Auckland, New Zealand. In this heater the cream is subjected to three stages of vacuum, each greater than the preceding one. The cream is rapidly heated to 190° to 200°F. in the first stage which operate at a vacuum of about 6½ to 11 inches. As the cream enters the second stage, operating at a vacuum of between 15 and 20 inches, it vaporizes for, whereas its temperature is nearly 200°F. as it enters this stage, the high vacuum reduces its boiling point to about 162° to 179°F. The cream is whirled as it enters this stage which causes it to pass down the wall of the chamber. Any odours or gases, volatilized under these conditions, are removed as they condense in the cold water spray of a condenser operating in this stage. On entering the third stage, operating at a vacuum of about 28 inches, the cream is again whirled around the wall of the chamber and again boils vigorously as the boiling point is further reduced, to about 100°F. by the greater vacuum. Additional materials may volatilize under these conditions and be removed by another condenser. The Vacreator, therefore, not only serves as a heater for pasteurization purposes, but it likewise aerates the cream, eliminating flavours and odours, and cools it to about 100°F.

Cream Separator

The mechanical cream separator was invented by Wilhelm LeFeldt in 1872, but was improved somewhat and made continuous by Dr. Gustav DeLaval of Sweden about 1879. The modern separator is a precision mechanism that is capable of removing 99·5 per cent or more of the fat from whole milk.

Milk is supplied to the separator bowl either at the top or at the bottom. It is always fed into the bowl at the centre of the axis on which it rotates. The milk is then distributed between the separator discs or plates where it is confined in thin films to facilitate separation. The principle of separation and the factors which affect the efficiency of the operation of the centrifugal separator are discussed in Chapter VIII. The skim milk and the cream are ejected

from the bowl at separate levels; by means of collecting covers and spouts these two products of the separation of milk are drawn off separately.

The gears with which the bowl is driven must be well lubricated. To make this possible they are enclosed in the frame of the machine and partially immersed in oil, the level of which is maintained by frequent additions. During operation the oil is carried from one moving part to another so that all wearing surfaces involved are well lubricated to prevent unnecessary wear. The upper spindle bearing or neck bearing is fitted with a special spring mechanism by which the bowl is, to some extent at least, automatically balanced during its operation.

The bowl must be perfectly balanced. Operating as it does at such a high speed the slightest variation in the balance of the bowl or the slightest deviation from a vertical position of the spindle will cause considerable vibration. This rapidly wears the moving parts reducing the life of the machine as well as the efficiency of separation or the completeness with which the fat is removed from the skim or separated milk.

Cold Store Rooms

The different parts of the mechanical refrigerator and its operation are discussed in Chapter VIII. The refrigeration system may be either the brine system or the direct expansion system. The storage rooms must be conveniently located and so constructed that the desired temperature can be maintained continuously at the lowest possible cost. The size of the rooms will depend upon the quantity and type of materials to be stored. The floor, walls and ceiling must be well insulated. The doors must be constructed so that the least possible loss of refrigeration occurs between the doors and the door jambs.

Rooms which are to be maintained at low temperatures should be equipped with a double doorway between which is a space sufficient to accommodate whatever type of load may be taken into the cold store room. The outer door is opened to admit the load into the interdoor space or anteroom after which the outer door is closed before the inner one is opened.

Cork has proved to be one of the best insulating materials because of its low thermal conductivity and light weight. There

are other materials that are used for this purpose, although they are not usually so readily available. One of the newest is glass fibre. This material has particular possibilities where damage by white ants may occur. These common and very destructive insects do not attack glass fibre.

The thickness of the cork insulation will depend upon the temperature it is intended shall be maintained inside the cold storage room. A thickness of four to six inches is ordinarily considered sufficient for rooms that are to be maintained at about 40° to 60°F. The thickness will increase as the temperature is reduced, until it is about 10 to 12 inches thick where the room is operated at 0° to-10°F. Corkboard for insulating purposes is available in varying thicknesses, usually 2 to 4 inches. Thicker insulation is made by using several thicknesses of such board.

Coolers

Any piece of equipment used for heating milk or milk products in the creamery usually may be used for cooling. Pasteurizing vats are nearly always used for cooling milk as much as possible with tap water, for this material is cheaper than refrigeration. High tap water temperatures common in India, however, make this means of cooling less useful than elsewhere. Nevertheless, tap water is economical for cooling to between 90° and 100°F.; thereafter refrigerants or ice must be used. Tap water may be used either in the pasteurizing vat or in a surface cooler.

The surface cooler consists of a series of parallel pipes placed one above the other and so connected that the cooling medium, tap water, brine or expanding refrigeration gas, may pass in opposite directions through successive pipes. The outside surface of the pipes is tin or nickel-plated or the pipes are made of a milk-resistant metal such as stainless steel. The cooling medium passes through the pipes from bottom to top whereas the milk flows over their exterior from top to bottom. Such coolers may or may not be covered to protect the milk from contamination from the atmosphere. The capacity of coolers depends upon the number, diameter and length of the pipes of which they are made as well as the supply of refrigerant and the rate of milk flow.

Coolers constructed much like tubular heaters are also used,

although this design is not so common as that just explained. Another type which is occasionally used in small milk plants in India is the drum cooler. It consists of a cylinder which is filled with a mixture of ice and salt and rotated in a horizontal position. The milk flows over this drum in a thin film and is collected as it drains off from the bottom.

Cans and Pails

Cans must be constructed of very strong and durable materials which are not dissolved by milk. The heavy iron can that is uniformly and completely coated with tin is very satisfactory. The can should be so constructed that it can be easily cleaned and sterilized. It should be of one-piece construction with no corners which are inconvenient and cannot be easily reached for cleaning. The umbrella type lid has been found most satisfactory in preventing both the entrance of dust and dirt or other contaminating agencies and the contamination of the mouth and lip of the can. The capacity of the can must be adequate for the purpose for which it is employed, yet it must not be so large that when filled its weight is too great for one man to handle conveniently. An eight-or ten-gallon can is probably the most satisfactory for general use, although for certain purposes, such as the retail delivery of milk, smaller cans are better. For long distance transportation of large volumes of milk the ten-gallon can is a very practical and common size.

Smaller containers, that is buckets and pails, are made of wood, earthenware or metal. Can-shaped wooden buckets are sometimes used in the hills for delivering milk; in Burma a cylindrical container made from a portion of a bamboo pole is used (18). Wood is light in weight, durable under ordinary usage and inexpensive. It is very porous, however, and cannot be properly cleaned and sterilized.

Earthenware containers are of a variety of sizes and shapes. This type of container is very cheap and is available almost anywhere. The unglazed earthenware containers, so common in all parts of India, are not durable, particularly when wet or filled. The porous nature of this material makes it, like wood, difficult to clean and sterilize for which reason it will be of little use to the industrial dairyman supplying high quality milk to urban consuming areas. It may

continue to be useful for single service containers until paper is more widely used.

Metals commonly used for buckets and pails are brass, copper, galvanized iron, tinned iron and stainless steel. The action of milk on these different metals is discussed in Chapter V. Mechanical features of the utensils which are most important are their durability and their manner of construction. Durable pails may be made from any of these metals, with the possible exception of copper. The strength of a pail will depend upon the thickness or guage of the metal sheet from which it is made and the manner and extent of reinforcement at the bottom and at the handle attachment. The heavier the metal the more durable the pail. Pails should be made of one piece of metal pressed into the proper shape. This assures the corners, which should be rounded, being tight and not liable to open as a result of bending or other damage; it eliminates seams in the side or the body of the pail, resulting from the overlapping of the two ends of a piece of flat metal sheet used for other types of pail construction. Rivets should not be used, all parts are to be welded together. A strong iron base should be attached to the bottom of the pail body on the outside. This will serve as a stand for the pail and will protect the bottom and the bottom corner of the pail. Tinned iron or stainless steel make the best buckets and pails. The cover-top pail is ideal as a milking pail.

Scales and Balances

Numerous types of scales and balances are required in the milk plant. A platform scale may be used for general purposes, preferably a dial scale from which weights can be read on a large dial by means of a pointer. Ordinary spring scales for handling up to 50 to 100 pounds are frequently used. In weighing the milk samples for testing, in the testing of butter and other such operations a special type of scale, known as a torsion balance, is sometimes used. The satisfactory operation of the milk plant, particularly if several milk products are manufactured, requires a variety of different types of weighing equipment with which quantities varying from fractions of a gram up to several hundred-weights may be handled at one time. Accuracy is imperative whatever the type of equipment used.

Churns

Three common types of churns are in use at the present time. Churns are made of wood or, more recently, of metal. The wooden ones are barrel-shaped and may or may not be fitted with shelves or benches which increase agitation and facilitate churning, and rollers which serve as benches during churning but which are used primarily for working the butter. Metal churns are rectangular, having neither benches nor rollers. The capacity of churns varies from as little as 5 pounds or so of cream in the small hand models to as much as 7000 pounds in the largest industrial models. The standard factory churn is designed for 1000 pounds of butter, although there are those, such as one at Polson Limited, Anand, designed for 400 pounds.

The End-Over-End Churn

The end-over-end churn is a barrel churn suspended at right angles to its long axis so that while it is rotating, either by hand or by mechanical power, the cream is agitated by tumbling back and forth from end to end in the churn. The butter granules so obtained are worked on a separate working table to which is fitted a large corrugated wooden roller. The butter is worked between the roller and the table surface.

This churn is made of wood, only in small sizes. Its main criticism lies in the fact that the wooden working table must be exposed to the atmosphere whereby it becomes contaminated with bacteria, yeasts and moulds, particularly the latter. Proper sanitation of the working table is very difficult, consequently the mould content of butter made with this equipment is commonly higher than desirable.

The Combined Churn and Worker

There are two types of large barrel churns; the combined churn and worker unit and the rolless unit. There are two kinds of the combined unit, *viz.*, that with the working rollers fixed inside the churn and that with removable rollers. Both of these are made of wood. The first may be a single-roll churn with one roller, a double-roll churn with two rollers, or a multiple-roll churn with four or six rollers. These churns open on the side or on the end; that with removable rollers opening at the end. The latter has two rollers

mounted on a truck in such a manner that for working the butter they may be wheeled into position, the rollers entering the churn door and the truck passing beneath the churn. A gear on the rollers meshes with a gear inside the churn for driving the rollers.

Benches or shelves are fitted inside these combined churns to increase the agitation of the cream and facilitate churning. These benches are fixed parallel to the long axis of the churn; their inside edge being likewise parallel to this axis. The churn operates at two speeds. During churning the speed is 60 to 65 R.P.M. when the built-in rollers remain idle and serve as additional benches; the removable rollers are outside the churn at this time. During working the speed is 20 to 25 R.P.M. when the rollers are independently operated, the built-in rollers being driven by engaging the driving gears by means of a lever on the gear assembly at one end of the churn, the removable rollers being driven as explained above. The butter is carried upwards by the benches as the churn revolves and is fed into the rollers. The greater the number of rollers the fewer the revolutions of the churn necessary for proper working of the butter.

The main disadvantages of this type of churn have to do with both its sanitation and its operation. Where the rollers are built-in, power must be transferred to the interior of the churn to drive them during working. This is done by passing a shaft through the end of the churn. The boxing in the churn wall which is required to support this shaft must be so constructed that it may be properly lubricated without any of the oil getting into the butter; it must be so packed that cream and butter-milk do not leak through it; and it must be built to permit proper cleaning and sterilization so it will not prove a source of contamination of the butter. A boxing which will meet all these requirements satisfactorily has not yet been designed. Rollers, on the other hand, which are removable are exposed to the atmosphere of the creamery while not in use. The difficulty of cleaning these wooden rollers, to avoid their contributing considerably to the mould content of the butter, has never been satisfactorily overcome. They are liable, therefore, to the same criticism as the working table used with the end-over-end churn. Apart from these two considerations the interior of either kind of combined churn and worker unit can be properly cleaned.

The Rolless Churn

In an attempt to overcome the difficulties of the combined churn and worker equipment, the rolless churn has been developed. The wooden rolless churn is made much as the combined type, except that the rollers are absent and the benches are constructed either diagonal to the axis of rotation or their inside edge is diagonal to that axis. The metal churn has neither benches nor rollers, although some of them have a ridged interior surface. The rectangular shape of the body of the metal churn, however, provides the necessary irregularities for proper churning and working. During churning this type of churn agitates the cream much the same as the end-over-end or combined types. During working of the butter, however, the butter is picked up by the benches, carried to the top of the churn and dropped. As the butter mass strikes the bottom of the churn it tends to spread and flatten. Furthermore, as the diagonal benches, or the irregularities of the interior surface of the metal churn, pick up the butter mass and carry it upwards during each revolution the mass is worked together somewhat endwise.

The rolless churn is becoming more popular in some countries because it can be more satisfactorily cleaned than the other types. The boxing of the combined churn and worker is eliminated as is also the need for working butter with equipment, a working table or rollers, that cannot be satisfactorily cleaned because it is continuously exposed to the atmosphere.

Several advantages are given for the rolless churn among which are: the cream is churned as much as three or four minutes quicker, a lower yeast and mould count results in the butter and the exhaustiveness of churning is equal to that of other types of churns. This churn operates at one speed, that is about 25 R.P.M., during both churning and working.

Milk, Bottles, Bottle Fillers and Bottle Cappers

A variety of different kinds of milk bottles are used in the dairy industry. The type of seal used will determine the shape of the mouth of the bottle. The size of the bottles is usually based on pounds, seers, quarts or fractions or multiples thereof. Bottles are usually made of glass, although paper bottles, called single service containers, are used in

some foreign markets. The glass bottles are usually round; paper bottles may be round or square. The latest glass bottle is square (94). It is claimed that 45 per cent more milk can be stored in the same space when square bottles are handled in newly designed bottle cases and that they occupy one-third less space in the delivery truck.

Common methods of sealing milk bottles involve the use of the paper disk or cap, the paper disk and a paper hood tied with a wire, or the aluminium or paper-lined crown type cap. From a sanitary point of view, the paper disk alone is unsatisfactory for it gives no protection to the pouring lip of the bottle which should not be exposed to the dust and dirt of the atmosphere nor to the danger of contamination during the handling of the bottle after filling. The only satisfactory method of sealing the milk bottle is one which protects this pouring lip. The ideal method is by use of the paper disk and the paper hood which is tied with a wire. Seals which protect only a portion of the pouring lip are to be preferred, however, to the disk alone.

Two types of bottle fillers are used, the gravity flow and the vacuum fillers. These may be simple hand operated machines handling a maximum of four to six bottles at one time, or large power driven rotary fillers capable of handling several hundred bottles an hour. The vacuum fillers are, and the larger gravity fillers usually are, of the rotary type. Most of the large fillers are equipped with automatic capping and sealing devices. Special fillers and sealing devices are used for most paper bottles, although some are designed to make use of the common paper bottle disk or cap and can be filled and capped in the regular equipment designed for the standard glass bottle.

CHAPTER VIII

COMMON DAIRY PROCESSES

Many processes are commonly carried out in the dairy which have considerable influence upon the type and quality of product which is produced. Milk and milk products are largely used as human foods. It is primarily for this reason that so much care is now given and must be given in the preparation of the products of the dairy to assure their being clean and safe. Good quality products must be produced and their quality must be maintained if the consumer is to get the kind of food which he deserves if he is to maintain good health and if he is to be supplied with the food nutrients his body requires. Some of these processes are discussed in detail below.

Heating and Cooling

Physical Principles Involved

Heat is a form of energy produced by the vibrating action of the molecules of a body (8). Three kinds of heat may be recognised for our purposes, *viz.*, sensible, latent and specific. Sensible heat is that heat which may be felt or measured by a thermometer. Latent heat is that heat contained by a body as hidden heat and which must be absorbed before the body can be converted from a solid to a liquid or a liquid to a gas, or which must be released to reverse these changes. This kind of heat cannot be measured by use of a thermometer as it causes no change in temperature. The latent heat required to convert a substance from a solid to a liquid, with no change of temperature, is called the latent heat of fusion; this is 144·0 B.T.U. for one pound of pure water at one atmosphere of pressure. The latent heat required to convert a susbstance from a liquid into a gas, with no change of temperature, is called the latent heat of vaporization ; this is 970·4 B.T.U. for one pound of pure water at one atmosphere of pressure. Specific heat is the amount of heat required to change

the temperature of a substance one degree as compared to the amount required to produce the same change in an equal quantity of pure water. The specific heat of milk above freezing is 0·900 and below freezing 0·462 (12).

Temperature is a measure of the sensible heat of a substance. It is expressed in degrees by means of several standard scales or thermometers. Appendix VII shows the relationship between the Fahrenheit and Centigrade scales; also included are formulæ for converting readings on either scale into readings on the other.

Pressure tends to restrict the movements of molecules. This results in an increase in temperature as the pressure is increased or a decrease in temperature as the pressure is decreased. Such effect is more noticeable with some substances than with others. With variations in pressure, the temperature at which freezing and boiling occur will vary. Milk boils, for example, at about 143°F. during the condensing of milk in a vacuum of 23·5 inches. The atmosphere exerts a certain amount of pressure which varies with the altitude or height above sea level. The pressure of the atmosphere at sea level is about 14·7 pounds per square inch, sufficient to support a mercury volume 760 millimetres or 30 inches (actually 29·92 inches) high in a perfect vacuum. This is called one atmosphere of pressure, frequently referred to as standard pressure. Likewise, as the concentration of a solution increases, its boiling point increases and its freezing point diminishes, as indicated by the fact that a mixture of 29 parts of ordinary salt or $NaCl$ and 100 parts of ice has a melting point of —6·16°F. (92) instead of 32°F., the melting point of pure water ice. Milk, because of its content of sugar and other soluble substances, boils at 212·3°F. (47); zebu milk freezes at —0·546°C. and buffalo milk at —0·543°C. (97).

The preparation of milk for marketing purposes or the manufacture of milk products commonly involves heating or cooling operations. Heating or cooling do not always cause changes in temperature, however, for not all heat which a body contains is sensible heat. Heating involves an increase, cooling a decrease, of sensible and/or latent heat. Heating and cooling are terms commonly used in reference to temperature changes only. The discussion here, however, includes those changes in heat content which occur also when physical changes take place.

Heat Transfer—According to Sommer (93), the rate of heat transfer from one body to another depends upon: (1) the temperature gradient, (2) the renewal of the surface films of the liquids or gases on opposite sides of the dividing wall and (3) the thermal conductivity of the wall. Steam, hot water and hot milk are usually employed for heating purposes in the dairy, whereas cold milk, cold water, ice and mechanical refrigeration are used for cooling. The wall dividing the two substances involved in common heating or cooling operations in the dairy is made of a material which either conducts heat as rapidly as possible, consistent with durability and chemical stability in the presence of milk constituents or washing materials, or as slowly as possible. Tin coated copper is an example of the former, cork insulation of the latter.

Units of Heat—Heat energy may be measured in terms of its effect upon water. Two common units are recognised, each of which is used in the application of the principles of thermodynamics in the dairy industry. A calorie is the amount of heat required to increase the temperature of one gram of pure water one degree Centigrade at one atmosphere of pressure. The kilogram calorie, usually written Calorie, is equivalent to 1000 calories. This unit, the kilogram calorie or Calorie, is used in calculating the heat energy value of foods and the heat energy requirements in human or animal nutrition. The British thermal unit, usually written B. T. U. or B. t. u., is the amount of heat required to raise the temperature of one pound of pure water one degree Fahrenheit at one atmosphere pressure. This unit is more commonly employed in reference to steam, hot water and refrigeration, or in the industrial application of thermodynamics.

All matter exists in one of three states at a given temperature and pressure. These are as a solid, a liquid, or a gas. Changes of pressure may cause a substance to change from one state to another with no change in temperature. As the temperature of water increases from 25°F., it takes one B. T. U. per pound of water for each degree to increase its temperature to 32°F. at which it is still ice. The latent heat of fusion, or the heat required to convert it into water *with no change of temperature*, is 144 B. T. U. per pound. Thereafter, from 32° to 212°F. one B. T. U. is required per pound of water for each one

degree increase in temperature. Again at 212°F. the latent heat of vaporization requires 970·4 B. T. U. per pound of water to convert it into steam *with no change in temperature.* It requires, consequently, 1301·4 B. T. U. (7+144+180+970·4=1301·4) to convert one pound of water at 25°F. into steam at 212°F., assuming no loss of heat in the process. These figures are on the basis of the temperature and physical changes taking place at one atmosphere of pressure.

Common heating operations used in creamery work include the making of steam, the heating of water, the sterilization, boiling, pasteurizing, cooking, condensing and drying of milk or milk products and the sterilization of dairy equipment ; cooling operations include the cooling of milk and milk products, refrigeration and freezing.

HEATING

For practical purposes milk and water may be classified on the basis of temperature in somewhat the following manner :

frozen (ice)	32°F. or less	warm	100°F. to 120°F.
ice cold	32°F. to 40°F.	hot	120°F. to 150°F.
cold	40°F. to 55°F.	scalding hot	150°F. to 190°F.
cool	55°F. to 75°F.	boiling hot	190°F. to 212°F.
luke warm	75°F. to 95°F.	vaporized steam	212°F. or more

This is by no means a rigid classification but in a general way it does suggest the temperature ranges that are referred to by the different terms. Actually the terms hot and cold are themselves relative; for example, one blows his breath on hot tea or food to *cool* it and also on his hands to *warm* them in cold weather.

Hot water or steam are used as a source of heat for most heating operations. Such material can be provided at a central place, by means of a boiler, and transported through pipes to different parts of the plant. Individual heating units at each place in the creamery where heat is required are not ordinarily practical. Hot water or steam is usually produced by burning coal or wood, possibly oil, which are always accompanied by considerable dust and dirt, *viz.*, coal dust, ashes and smoke, or odours and fumes, which are not desirable where

food products such as milk are handled. Water may be heated or steam produced in a room apart from those in which they are to be used, and made available anywhere they are needed by means which will meet even the most rigid sanitary requirements. Hot water or steam pipes can be effectively insulated by asbestos covers to prevent appreciable losses of heat which, like all losses, increase costs.

Production of Steam and Hot Water—Steam or hot water is prepared in an open tank or in a boiler. A steam pressure of around sixty pounds per square inch is sufficient for the regular creamery supply; higher pressures may be required, however, for operating a steam engine, a large vacuum pan or a powder mill.

The boiling point of a liquid is determined by, among other things, the pressure of the atmosphere above it. The pressure of saturated steam—steam in the presence of water from which it is generated—determines the temperature at which water boils. The latent heat of vaporization is different at different temperatures of boiling. Two thermodynamic differences exist between hot water and steam, *viz.*, a difference of temperature, except at 212°F., and the presence of latent heat of vaporization in steam which is not found in hot water.

There are advantages and disadvantages in both steam and hot water as heating media. The latent heat of vaporization in steam makes it a more potent heating medium than hot water. This heating medium is condensed to a considerable extent on cooling so that a very small volume of discharge water or condensate must be handled as compared to that necessary when hot water is used. Steam is particularly useful in flash pasteurization, the operation of the vacuum pan, and for sterilizing equipment. Considerable care must be taken when steam is used for heating milk and milk products to prevent the scorching and burning of milk solids which results in the production of undesirable flavours and odours in the product. This may occur with hot water as well. The high temperature of steam, 212°F. or higher, and its latent heat makes it more dangerous for those working with it than hot water, although this must not be understood as minimizing the danger of the latter. Steam may be considered, for example, as water which has gone crazy with the heat, with precautions being taken accordingly while handling it.

The temperature of tap water varies with the season; it is

between 70° and 84°F. in most parts of India throughout the year. By the use of water the temperature gradient between the heating and the heated media can be controlled as desired. With steam, considerable agitation of the product being heated is required if the undesirable effects of a large temperature gradient are to be avoided. The results of excessive agitation are explained elsewhere.

Pasteurization—Milk and milk products may be exposed to various temperature-time treatments to destroy all or part of the micro-organisms present. Pasteurization and sterilization are terms frequently used interchangeably to refer to such treatments. Complete sterilization involves the destruction of all organic life in the milk, including the most resistant organisms and their spores. Pasteurization is generally used in the dairy industry in reference to the destruction of all pathogenic or disease producing organisms in milk or milk products. The confusion comes in reference to degrees of destruction between these limits. Louis Pasteur, the great French biochemist after whom the process of pasteurization is named, first applied a temperature-time treatment to wine in 1864 to prevent it from scouring. Since, as is true of milk, organisms responsible for the scouring of wine are not always pathogenic to man, it would seem justifiable to use the term pasteurize in reference to the destruction of undesirable organisms in milk whether they be pathogenic or disease producing for man or, using the Greek words from which pathogenic is derived, *pathos gannao* (to cause disease or suffering) in an economic or technical sense. Although this meaning of pasteurization would include the degree of destruction referred to above as sterilization, it seems desirable that we use sterilization to mean complete destruction and pasteurization to mean partial destruction. Pasteurization, therefore, is a process by which milk is exposed to a temperature-time treatment sufficient to destroy a part of the organisms present. From a public health point of view, pasteurization is the exposure of milk or milk products to a temperature-time treatment sufficient to destroy all pathogenic or disease producing micro-organisms present, thereby rendering the milk safe as a food.

Milk or milk products are sterilized under certain conditions. Evaporated milk is commonly sterilized after being tinned by

exposing the sealed tins to one of two different temperature-time exposures (44). In the *batch method* the sealed tins are heated to 240°F., under about 10 pounds steam pressure, for 15 minutes, followed by cooling to 75°F. In the *fractional method* the sealed tins are heated to 100°F. in water for 8 hours. The water is allowed to cool gradually. Four hours later it is again heated to 149°F. for 30 to 40 minutes. The cans are then cooled and stored. Milk may be sterilized for use in the bacteriology laboratory or for the manufacture of special types of milk such, for example, as milk cultures of *Lactobacillus acidophilus*.

Boiling occurs at that temperature at which a substance may exist as either a liquid or a gas. At this temperature, 212°F. for pure water and 212·3°F. for milk at atmospheric pressure, the continued absorption of heat causes vigorous motion of the unvaporized liquid as well as rapid evaporation. The characteristic boiling motion of the liquid indicates this temperature has been reached. So long as any liquid remains, the temperature will not increase much further. Obviously, therefore, boiling is a more severe temperature-time treatment than pasteurization which destroys 90 per cent or more of all organisms present in milk. The boiling of milk as it is so generally practised in the Indian home, therefore, renders the milk safe. In the absence of routine pasteurization of all market milk and in view of the possibility of recontamination with pathogenic organisms subsequent to pasteurization, boiling the milk before it is consumed should continue to be a regular practice, in spite of any detrimental effects it may have on the nutritive value of the milk. Only where milk can be pasteurized in the home or where milk is available that has been pasteurized thoroughly and effectively in the milk plant or dairy, with every assurance that subsequent contamination is impossible, should it be consumed unboiled. Boiling needs to be continued only a second or two to render the milk safe.

The most heat resistant pathogenic organism ordinarily present in milk, in western countries, is *Mycobacterium tuberculosis*. This organism has a thermal death point of 140°F. for 20 minutes in milk (93).

For public health purposes milk may be pasteurized by one of three standard procedures. The equipment required

in each case is discussed under Dairy Engineering. These procedures are: (1) the vat, batch or holding method in which the milk is heated to 145°F. at which temperature it is held for 30 minutes and then quickly cooled; (2) the high-temperature short-time method, sometimes called the hot-short method, in which the milk is heated quickly to 165°F. at which temperature it is held 15 to 16 seconds and then quickly cooled; and (3) the flash method in which the milk is suddenly heated to 185°F. or higher and immediately cooled. The last method is seldom applied to fluid milk but is a common procedure for pasteurizing cream for butter making.

For special purposes milk may be pasteurized at different exposures from those just indicated. For *dahi* making the milk should be pasteurized by boiling a minute or so before being cooled and inoculated (22). In the propagation of a butter culture the milk is pasteurized at 180°F. for one hour (47) and for a cheese culture at 180°F. to 200°F. for one-half an hour (106).

Cooking—Heat treatments are frequently given in the manufacture of milk products which are known as cooking. Such treatments may or may not bring about changes in the milk constituents that would classify them as cooking in a technical sense. In most cases, however, they are treatments to facilitate partial or complete drying or coagulation, such as the cooking of cheese. Not all heat treatments other than pasteurization, sterilization and boiling are, however, referred to as cooking; the heating of ghee during blending is an example. On the other hand these treatments, particularly boiling, are at times called cooking.

Drying—The condensing and drying of milk require heating sufficiently to evaporate in whole or in part the moisture contained in the milk. The temperatures employed vary with the pressure under which the operation is carried out, in the atmosphere or in the vacuum pan, while the duration of exposure will depend upon the original moisture content, the degree of desiccation required and the supply of heat.

Heat Sterilization of Equipment—Dairy equipment and utensils may be sterilized by heat or by chemicals. The latter is discussed elsewhere. Moist heat is more effective than dry heat. In either case, however, sterilization must be followed by complete drying to be effective. Drying should be accom-

plished by allowing the moisture present, following sterilization, to drain away or evaporate. *A cloth should never be used to dry equipment or utensils by wiping.*

According to the definitions given here, dairy equipment and utensils are sterilized by heating only when treated in the autoclave, otherwise they are pasteurized. The former term is used, however, for two reasons, *viz.*, to avoid introducing a new meaning of the latter that does not receive the support of popular usage in the dairy industry and to indicate the degree of destruction of organisms, that is, for practical purposes, actually obtained if the procedure is accurately followed.

The sterilization of utensils and small pieces of equipment with steam or hot water may be done by use of an autoclave or retort, a steam chest, a steam jet or with hot water (93). In the autoclave the utensils are subjected to 15 pounds of steam pressure, giving a temperature of 249·7°F., for 30 minutes. In a steam chest the steam is under no pressure so that the temperature is practically 212°F.; the utensils are maintained at this temperature for 20 to 30 minutes. By use of the jet, live steam is directed into each utensil so that a temperature of 210°F. is reached by the entire utensil and is held several minutes. With hot water, utensils must be immersed for 5 to 10 minutes in water that is maintained at 180°F.

The sterilization of larger equipment with steam or hot water is more difficult. Steam should be applied to an enclosed area. It should be allowed to flow into the container until a temperature of 180°F. or more is reached, as indicated by the temperature of the condensate which flows from the equipment. Hot water can be used for all such equipment by passing boiling hot water over any surface, with which milk comes into contact, until it reaches a temperature of 180°F. which is maintained at least one minute.

Hot dry air is merely used in the dairy for purposes of sterilizing equipment and utensils. This medium is used, however, for heating purposes in the drying of milk by the spray process. Where the climate is such that the dairy requires heating, hot dry air may be used, although this is rarely, if ever, necessary in India.

Hot milk may be employed for heating purposes, as a matter of economy, in regenerative heating discussed on page 170.

Cooling

One of the principles which makes mechanical refrigeration possible was stated in an earlier paragraph of this section, *viz.*, and increase in pressure restricts the movement of molecules, causing a rise in the sensible heat content of the substance involved, while a decrease in pressure permits greater molecular freedom with a resulting decrease in a sensible heat content. Stated another way, an enclosed gas gives off heat as the pressure to which it is exposed increases, or absorbs heat as the pressure decreases. In the mechanical refrigerator a volume of gas is compressed in the compressor; as a result of this it becomes hot. While yet under pressure it is cooled in the condenser by air or water. When the pressure is again released at the expansion valve the gas, which usually has liquefied in the condenser, passes into the evaporator and expands due to the release of the pressure. Here it absorbs heat from whatever is surrounding it. The low pressure gas is then returned to the compressor.

Mechanical refrigeration is based also on a second principle, that is, the utilization of the latent heat of a gas that may be liquefied at ordinary temperatures under pressures which can be readily produced by mechanical means. Gases regularly employed for industrial refrigeration purposes are ammonia, carbon dioxide and sulphur dioxide; those for household refrigeration are methylene chloride, methyl chloride and possibly others. Ammonia freezes at—103°F. and boils at 28°F. at atmospheric pressure; its latent heat of fusion is 194·0 B. T. U. and its latent heat of vaporization is 588·8 B. T. U. (8).

The purpose of a compressor is to increase the pressure on the refrigerant sufficiently that its latent heat of vaporization can be removed by air or water at ordinary temperatures. This is done in the condenser. Air or water are used for this purpose as they are readily available in large quantities, at low cost. As sufficient heat is removed by this means the gas, still under pressure, liquefies. The liquid refrigerant then passes on into a supply tank and then through an expansion valve. The pressure is released as the refrigerant passes this valve so that it then vaporizes, absorbing its heat of vaporization together with a small quantity of sensible heat, as it does so. This physical change of the refrigerant from a

liquid to a gas with its consequent absorption of large quantities of heat reduces the temperature of whatever surrounds the evaporator.

The characteristics of an ideal refrigerant are a low boiling temperature at a low pressure, a large latent heat of vaporization, a small specific volume, and a considerable degree of safety to human life. The latent heat of vaporization must be removed and the refrigerant must become a liquid in the condenser; also, the refrigerant must vaporize when allowed to expand, as it passes through the expansion valve, in order that the latent heat of vaporization is again absorbed. Refrigeration is a means by which heat is removed from a volume either of air in the cold store, of liquid such as brine or water, or of milk or milk products and deposited in the air or water utilized in the condenser.

Mechanical Refrigerating Systems—Refrigeration may be accomplished by direct or indirect means. In the direct expansion system the evaporator is constructed in the cold store room or built into the equipment, such as a cooler, pasteurizing vat or ice cream freezer, in which cooling is carried out. The refrigerant is transferred directly from the condenser and supply tank to the expansion value at the intake of the evaporator. The heat absorbing capacity of the refrigerant during evaporation is utilized directly in the cooling operation.

In the brine system a quantity of calcium chloride ($CaCl_2$) brine is cooled by the direct expansion of the refrigerant in an evaporator immersed in the brine. The brine is pumped from place to place where needed; the discharge brine, which has absorbed a quantity of heat, is returned to the brine supply tank. The strength of the brine must be sufficient to keep it from freezing at the temperature at which it is used. This may involve a concentration of up to 20 per cent calcium chloride for ordinary cooling operations. This concentration gives a brine which freezes at —1·4°F. (8).

The direct expansion system, in spite of certain disadvantages as compared with the indirect system, is rapidly replacing the latter in large commercial dairies.

Cold Storage—Cold storage temperatures will vary with the different milk products and will depend upon the purpose and length of storage. In most cases, bacterial changes may also be controlled by regulating the temperature of storage.

12

The cold storage temperatures recommended for milk and milk products are listed in the following table.

Cold storage temperatures recommended for milk and milk products

Milk	32° to 34°F. (74) for 'storage' less than 50°F. (93 and 31) 35°F. (12) for 'cold storage'
Butter	18° to 20°F. (12) for 'cold storage' a few weeks 0° to—20°F. (74) for 'cold storage' several months 32° to 40°F. (74) for 'holding a few days'
Cheese	34°F. (12) for 'cold storage' 40°F. to 65°F. (93) 40° to 50°F. (84) 'slow curing' 60° to 65°F. (84) for 'fast curing'
Ice cream	0°F. (93) 0° to—10°F. (74) for 'hardening'
Cream	32° to 34°F. (74) for 'storage' 45°F. (44) for 'cooling'
Condensed milk	63°F. (44) for 'cooling'
Evaporated milk	40° to 45°F. (44) for 'cooling'
Dried milk	Note: No temperature is specified. It is essential, however, that the storage room be dry and cool, preferably below 70°F.
Ghee	Note: No temperature is specified. It is essential, however, that the storage room be cold, preferably below 50°F.
Khoá, *Chhená*, *Khir* and *Rabaṛi*	Note: No temperatures are specified. It is essential, however, if noticeable bacterial growth is to be retarded for a few days, that the temperatures be below 50°F. Storage temperatures should be below 40°F.

Ice—Ice is manufactured by immersing tanks of water into calcium chloride brine, which is maintained at a temperature somewhat below 32°F., until the water freezes. The principal value of ice for cooling purposes in the dairy lies in the fact that it absorbs the latent heat of fusion of water as it melts. The temperature of ice is never more than 32°F. under standard pressure. Since many cooling operations in the dairy require that temperatures be reduced to 50°F. or less, the sensible heat contained in ice is likewise of some value. Natural ice is available in the higher altitudes of the Himalayas and may be used for cooling purposes. The bacteriological considerations make it advisable that ice never be added directly to milk or its products for cooling purposes. Innumerable pathogenic or otherwise undesirable

bacteria are found in water and freezing, as has been explained, will destroy only a very small proportion of them.

One pound of water in the form of ice at 32°F. will absorb 144 plus 18 or 162 B. T. U. as it melts and increases its temperature to 50°F. Apart from the specific heat of milk and the rather high losses of heat which are generally involved, it would require 58·6 pounds of ice at 32°F. to cool 100 pounds of milk from 145°F. to 50°F. The ice required for other cooling operations may be calculated. The excess of ice necessary to allow for losses that will occur under different conditions can only be determined by experience.

Ice cannot be used for all dairy cooling operations because it is a solid. It is frequently necessary to use ice for the cooling of water which is in turn used in milk coolers and milk vats, for example. The addition of salt to ice when making ice cream in a hand freezer reduces the temperature at which the ice melts. This makes the latent heat of fusion of water available at a temperature somewhat below 32°F. which facilitates quick freezing. The brine or direct expansion commercial freezer is designed to make very sudden freezing of the ice cream possible. It is partly for this reason that the texture or size of ice crystal in commercial ice cream is ordinarily much finer than that made in the hand freezer in which ice and salt are used. This question, however, is discussed in more detail under Ice Cream, Chapter XI, and Crystallization, Chapter V.

Tap Water—The temperature of water, as it comes from the ground in India is usually between 70° to 84°F. This is very high compared to countries with a less tropical climate. The lower the temperature of water the smaller the volume required for a particular cooling operation and the lower the temperature to which it is possible for other substances to be cooled. The high temperature of ground water in India makes it impossible to use water alone for cooling milk sufficiently to prevent bacterial growth. Water may be used for partial cooling of milk from the pasteurizing temperature. Ice, brine or other refrigerant is required, however, to lower the temperature of milk, for example, to 50°F. or less, the temperature necessary to retard the bacterial growth.

Cold milk may be used for cooling purposes, as a matter of economy, in regenerative cooling discussed on page 170.

Regenerative Heating and Cooling

Regenerative heating and cooling is sometimes used as a measure of economy when the method of pasteurization is continuous, such as in the hot-short or flash methods. The regenerator is constructed very much like a surface cooler, but with both interior and exterior surfaces made of materials with which milk may come into contact without deleterious effect. The milk which has been pasteurized is passed directly from the pasteurizer, while yet hot, from top to bottom over the regenerator, whereas cold or partially heated milk passes from bottom to top through the interior of the regenerator. Heat contained in the hot milk passes into the cold milk increasing the temperature of the latter while decreasing that of the former. The milk passing over the exterior of the unit is aerated and partly cooled at the same time as the milk inside is being partially heated.

The two portions of the milk, or the milk and the water or refrigerant in the case of coolers, are circulated countercurrent to each other for two reasons. These are to reduce the temperature differential throughout the heat exchange operation and to give better heat utilization. Were they to flow parallel, the temperature differential at the start of the exchange would be the difference between the starting temperatures of the two media. This differential would rapidly diminish until both media were of the same temperature after which there would be no further change. If the volumes of the two materials were the same, the common temperature would approximate the mean of the starting temperatures. This is the most that could be expected. On the other hand, were the two materials to flow countercurrent, the temperature differential would be greatly reduced and the maximum possible change would be the difference between the two starting temperatures, not the difference between the mean of and one of the two. These facts are illustrated in the following diagrams.

A		B		C	
185°F.	150°F.	185°F.	185°F.	185°F.	180°F.
↓	↓	↓	↑	↓	↑
168°F.	168°F.	168°F.	168°F.	170°F.	165°F.
↓	↓	↓	↑	↓	↑
168°F.	168°F.	150°F.	150°F.	155°F.	150°F.

In diagram A the two media flow parallel. The temperature differential is 35°F. in the beginning; this rapidly diminishes until the two temperatures are the same after which no further change occurs. In diagrams B and C the media flow counter-current. The temperatures of the two materials are the same at any point in diagram B; a differential of 5°F. is noted in diagram C. Whereas the maximum temperature change in either medium involved in A is about 17·5°F., that in B is 35°F. and that in C, 30°F. Diagram C probably represents more nearly than B what actually happens in this method of heat exchange because insufficient time is allowed in practice for that degree of heat exchange which would result in a common temperature in the two media.

Agitation

Continuous or intermittent agitation of milk, of milk products during their manufacture or of other materials is commonly necessary in the creamery. Agitation involves moving, disturbing or mixing substances by physical means. It is of use in dairy work mainly for two reasons, although other results such as the emulsification of fat may occur.

I. It mixes the constituents of the material being agitated, making it possible:

- a. to obtain a representative sample for testing purposes,
- b. to prevent the rising or settling of constituents or portions of the material,
- c. to prevent the formation of a skin at the surface of milk or of a dried and possibly scorched layer against the heated surface of the container during heating,
- d. to facilitate dissolving certain materials,
- e. to churn butter.

II. It makes uniform heat transfer possible during heating or cooling.

A sample is, by definition, a small portion or quantity of a substance which is qualitatively identical to the substance itself. A quantity of fore milk, for example, is not a sample of the milk produced by an individual cow at one milking. Only when all the milk obtained from a single complete milking is thoroughly mixed can a sample of that milk be obtained. The rising of fat makes agitation of a quantity of milk or cream necessary to assure accurate sampling.

Excessive agitation of whole milk or cream, particularly if the acidity be increased somewhat, may cause churning. Slight and moderate agitation will disturb the material sufficiently to prevent the accumulation of fat at the surface. Particles of cheese curd may be broken up by vigorous agitation shortly after cutting, whereas if the curd is stirred mildly they will retain their original size and individuality; if they are agitated during cooking they will not form a mat of curd in the bottom of the vat that prevents uniform heating, which is so necessary.

Should the surface of milk be undisturbed during heating a rather tough layer of dehydrated and coagulated material, mainly albumin and fat, will form. Such a layer, called a skin, is not desired in most cases, although in the manufacture of certain products, *rabaṛí* for example, this skin formation is required. Agitation should be applied according to the results desired from the heating of milk.

As the coagulation of milk tends to take place rather rapidly at the surface when it is being heated, so also this is liable to occur quickly at another liquid/gas interface when heating is sufficient to cause boiling. During boiling, gas bubbles form within the milk and against the surface of the container nearest the source of heat. Insufficient agitation at this time, in relation to the quantity of heat available which the milk is to absorb, may cause drying and coagulation of the milk solids making up the lamellae, or dividing films, between separate bubbles or between the bubbles and the inside surface of the container before the bubbles have left the container surface and risen to the milk surface. This causes the formation of a layer of dried milk at this site. Such a layer may adhere so strongly to the heated surface of the container that continued motion of the fluid milk immediately next to it does not move it. Once such a layer is formed it must be removed immediately to prevent it becoming scorched or burned, imparting a carmel, scorched or burnt flavour in the milk, and interfering with the free passage of heat into the milk. Such a layer of milk solids is a rather effective insulator.

Such things as sugar, salt, alkali neutralizers and washing powders are frequently dissolved in milk or water in the dairy. The rate at which they dissolve depends upon several factors among which is the surface area of the materials that is exposed

to the solvent. Finer crystals have a greater surface area for each unit volume. Consequently a quantity of such material can be expected to dissolve faster if finely powdered than if coarse or lumpy. The contact of a solvent is not as complete in the case of large or masses of crystals as otherwise. Agitation facilitates the dissolving of such materials by breaking up lumps or preventing their formation which might occur were they permitted to settle to the bottom.

The effect of agitation in churning is discussed under Butter, Chapter IX.

One of the many factors which influence the rate of heat transfer from one liquid to another is the renewal of the surface films on opposite sides of the dividing wall. This renewal is brought about by agitation or flow (93). Each film either gives up heat or absorbs heat, as the case may be, as it forms against the dividing wall. The longer a film remains in contact with this wall the more nearly its temperature approaches the material, if in motion, or the film opposite. As the temperature gradient is reduced the rate of heat transfer is reduced. Because agitation brings about renewal of these films, it is essential for rapid and satisfactory heating or cooling as usually practised in creamery work.

Certain effects of excessive agitation may not be desirable, however, in the dairy. Among these are emulsification of the fat, partial churning of the fat during the freezing of ice cream, and foaming. Particularly at high temperatures, excessive agitation may cause the breaking up of fat globule clumps or the division of the fat globules in milk intended for fluid consumption. Where milk is retailed in bottles and the cream line in the bottle is taken as an indication of the quality of its contents, the effect of the emulsification of the fat may be very undesirable. Because the cream fails to rise so rapidly as it might otherwise a poor or high cream line results; the milk is consequently considered to be of a poorer quality by many customers. The presence of small particles of butter, that is, butter granules, in ice cream is a defect which is easily detected and quite objectionable in this milk product. Excessive agitation during the freezing, particularly if the mix is placed in the freezer at a temperature above 40°F., may give rise to a degree of churning of the fat present. Reduced agitation at temperatures above 40°F. or use of a

mix at a lower temperature will overcome this defect. Foam acts as an insulator against the passage of heat. A layer of foam at the surface of milk in a vat during pasteurization may be improperly pasteurized and thereby serve as a source of contamination of the remainder of the milk after it is presumed that the process has been satisfactorily completed. Foam may also cause difficulty in the measuring of quantities of milk, or in the movement of milk through pumps, if it is excessive. As separated milk comes from the separator it is usually quite foamy as a result of the agitation the milk undergoes while passing through that machine. This foam will usually settle, however, if the separated milk is allowed to stand sufficiently long.

Aeration

As milk is drawn from the udder it contains a quantity of carbon dioxide (CO_2) which passes off into the atmosphere. Oxygen (O_2) and nitrogen (N_2) are dissolved in the milk during milking and subsequently during cooling, agitation, aeration or other treatment. Bacteria may produce certain gases while growing in milk (4).

Feed and weed flavours and odours may be present in the milk as it comes from the udder. In so far as these are volatile and/or soluble in CO_2, they may pass out with that gas as it is released. Materials soluble in O_2 or N_2 or which are volatile and either soluble in or absorbed by the fat may enter the milk either as it takes on these gases or on exposure to the materials. Such flavours and odours can be removed in part by aeration.

Aeration involves the exposing of milk to clean and pure air so that materials which are either soluble in the gases contained in the milk or volatile at the temperature employed may pass out of the milk, giving it a somewhat cleaner, more pleasing flavour and aroma.

This may be done during agitation, while pumping or pouring milk from one container to another, during heating or cooling, or by other means.

The solubility in a gas or the volatility of a substance depends upon, among other things, the temperature and pressure used. Aeration may be carried out at ordinary temperature and pressure or high temperatures and low pressures may be used. Some of the newer types of high temperature-vacuum pasteurizers are quite efficient in the re-

moval of off flavours as well as in the destruction of bacteria. The greater the surface area of the milk exposed the more effectively the flavour and odour is improved. If the milk or cream is finely atomized, therefore, the quality improvement is greater than if it is exposed as a film, such as on a surface cooler or regenerator.

For proper aeration the atmosphere to which the milk is exposed must be as clean and free of undesirable odours as possible, lest the process be incomplete or that atmosphere prove a source of other flavour or odour defects in the milk.

Coagulation

In the manufacture of *dahí*, *chhená* and cheese it is necessary to bring about the coagulation of the milk. Coagulated milk may appear much as it did before coagulation except that it becomes semi-solid; if agitated during or after coagulation, such milk may consist of irregular curdy masses immersed in a watery substance of a white to a yellow-white colour. Curd is coagulated milk protein; whey the watery substance which separates from the curd. In general, proteins coagulate on exposure to heat, alcohol, acids or enzymes. Whey can be more completely expelled from curd by increasing the temperature, the acidity, the quantity of coagulating enzyme, by pressing or by allowing the coagulated milk to stand for some time as a curd-whey mixture. The coagulation of milk in the dairy is usually brought about by means of acids, enzymes or heat.

Coagulation with Heat

Coagulation on heating takes place in two stages. Firstly, the proteins are denatured, possibly because calcium is released from the casein molecule which increases its hydration and also swells. Agglutination and coagulation follow as a result of the changes occurring in the electrical charges of the protein (4). The presence of developed acidity or of added acid causes changes in the charges of the protein molecule which aggravate coagulation when heat is applied. Other things being equal, the higher the temperature and/or the acidity the more rapidly milk coagulates. This explains why milk which is apparently normal sometimes coagulates on boiling, an observation that is frequently made when milk is boiled for

household use. Local heat coagulation at a liquid/gas interface, such as at the surface of milk or at the site of bubble formation in boiling milk, occurs more rapidly than at a liquid/liquid interface, such as at the non-fat/butter fat interface (21). The significance of the former is discussed under agitation.

Coagulation with Alcohol

Milk coagulates, under certain conditions, when mixed with equal parts of 68 to 75 per cent alcohol. The alcohol denatures the milk proteins by dehydration; the casein is precipitated as calcium caseinate (4). Colostrum; milk produced during extended lactation; milk which is otherwise abnormal, such as results from mastitis or certain general disease infections; and milk in which a reasonable degree of acid has developed coagulates on the addition of alcohol. Fresh, normal milk does not so coagulate. A simple though not always reliable test for the heat stability of milk is made by noting the extent and type of curd formation, if any, resulting from the addition of 2 millilitres of 75 per cent (by volume) ethyl alcohol to 2 millilitres of milk.

Coagulation with Acid

The addition of acid to or the development of acid in milk results in the combining of the acid with calcium caseinate forming calcium lactate and free casein; as the quantity of acid exceeds that necessary for that action, it reacts with the insoluble di-calcium phosphate to produce soluble mono-calcium phosphate and a calcium salt of the acid employed (32). This reaction occurs when the acidity has reached a point at which the electrical charge of the casein is in equilibrium with its environment or when the casein is electrically neutral. When expressed in terms of the hydrogen ion concentration at which this reaction takes place, it is known as the isoelectric point. The isoelectric point of milk casein is at a pH of 4·7, which indicates, according to Sommer (93), a hydrogen ion concentration of $2{\cdot}0 \times 10^{-5}$. This is an acidity of about 0·65 per cent expressed as lactic acid (32). In this method of coagulation of milk proteins only the casein is involved. Commercial casein produced by acid coagulation has a very low mineral content and is, for this reason, more useful for paints and glues than rennet casein which is valuable for plastics.

Lactic acid is used almost exclusively for coagulating milk by this method. It is the acid which develops naturally in milk, producing an acid or sour flavour, followed by coagulation. Acid producing bacteria, principally *Str. lactis*, produce this acid from lactose. Milk cultures of bacteria, whether acid producers or other types, used in the dairy are called starters. They are employed regularly in the manufacture of cheese, butter and such fermented milk products as *dahí*.

Coagulation with Enzymes

The coagulation of milk in cheese making or, on a much smaller scale, the making of Junket, is accomplished by the addition of the enzymes rennin or pepsin, usually the former. Rennin is obtained from the stomachs of young calves by drying, followed by soaking for a period of time in a solution of sodium chloride. Pepsin may also be present in a rennin preparation, called rennet, or may be prepared from hogs' stomachs (84).

Rennin affects only the casein in milk which is present as a colloidal calcium caseinate sol which is associated with a calcium phosphate sol. The presence of cations, or ions with a positive electrical charge, is necessary for rennin action which occurs best at 40° to 42°C. No action takes place below 15°C. or above 60°C. A soft curd is produced at low temperatures, whereas high temperatures cause a tough, stringy curd. Heating milk to 165°F. for 30 minutes or to boiling retards rennin action. The addition of $CaCl_2$ or an increase in the acidity of milk provides cations which aid the action of rennin (4). On the addition of rennin, there is a modification of the casein after which calcium caseinate is converted into calcium paracaseinate; thickening and coagulation follow. Rennet curd holds the fat and insoluble salts while the whey contains the lactose, soluble proteins and soluble salts. The minerals in commercial casein made with rennet make it more suitable for making plastics than that made with acid; the higher the acidity of the milk on the addition of rennet in the manufacture of casein, the lower the ash content of the curd or the finished casein. Coagulation with rennet occurs at a pH near the neutral point, consequently the growth of bacteria is not greatly retarded. Rennet curd is for this reason used in the

manufacture of those types of cheese which are cured to develop their characteristic body and flavour (21).

During the ripening of cheese, that is, the cheddar type made by the use of rennet, a curd-dissolving factor in the rennet, possibly pepsin or a substance with peptonizing properties, acts upon the calcium paracaseinate, with the aid of soluble calcium salts made available by the lactic acid, to break it down into various less complex materials which give this cheese its characteristic flavour (32 and 106). The actions of rennet and lactic acid in the manufacture and curing of cheese are shown below.

1. Calcium caseinate + Rennet → Calcium paracaseinate (106).

The calcium caseinate is present in the milk in suspension. The rennet used is a 2½ per cent aqueous solution. The calcium paracaseinate is insoluble in water and 5 per cent sodium chloride (NaCl) solution. In the absence of soluble calcium salts the calcium paracaseinate is not precipitated by rennet.

2. Calcium caseinate + Lactic acid → Calcium lactate + Free casein (32).

After the above reaction has taken place another follows, thus:

Di-calcium phosphate + Lactic acid → Mono-calcium phosphate + Calcium lactate.

The lactic acid involved in these reactions is produced in milk by bacterial action, as explained in Chapter VI. Calcium lactate is soluble, whereas the free casein is insoluble and consequently settles out. The di-calcium phosphate is an insoluble salt occurring normally in milk; the mono-calcium phosphate is soluble.

3. Calcium paracaseinate + Mono-calcium phosphate → Mono-calcium paracaseinate (106).

The calcium paracaseinate is made available by the rennet, as shown in formula 1. The mono-calcium paracaseinate is soluble in 5 per cent NaCl and is acted upon, as shown in formula 4, to give the end products of the cutting of cheese; such products are responsible for the flavour and odour as well as the body and texture of cheddar cheese and other similar types.

4. The peptonizing factor in rennet + Mono-calcium paracaseinate → Caseoses, peptones, amino acids and ammonia (106).

Straining and Filtering

Most sources of bacterial contamination in milk are also sources of debris, such as hair, manure, feed, dirt and flies. It is commonly thought that the removal of visible particles of such things from milk makes the milk clean. Not all dirt can be seen by the naked eye ; some dirt particles are too small while other dirt is soluble. The white colour and opaque nature of milk may make it difficult to see some dirt material in it which might otherwise be visible. The health of the human eye will determine the size of the smallest single particle visible to it; the number of particles and their proximity one to the other will determine the visibility of masses of particles. The size of the smallest particles or mass of particles that can be seen, however, is even larger than a clump of bacterial cells. Milk which appears clean, therefore, is likely to be dirty and may be unsafe. Few bacteria are greater than 10 microns in diameter, yet dirt particles 40 microns in diameter are known to pass through even the best cotton filter pad available for filtering milk. Consequently, the straining and filtering of milk is of questionable value in making it clean and safe. Visible dirt alone can be removed by the strainer or filter. One cannot rely upon the appearance of milk as an indication of how clean or how safe it is.

Milk may be strained by passing it through a fine wire gauze or a cloth; it is filtered by passing it through a special cotton felt pad. The filter removes finer particles than the strainer. Neither removes leucocytes, body cells or bacteria unless they get caught in the strainer gauze or cloth, the filter pad or on the larger particles that are retained.

Straining or filtering may remove considerable quantities of foreign material from milk and thereby have some value. It is far better, however, for the milk to be produced and handled so carefully that it does not contain debris which might be removed in this way. Of the manure which falls into milk, for example, only about one-eighth can be removed, the remainder being either liquid to begin with or later dissolved in the milk (43).

The Separation of Milk

The fat contained in whole milk may be used in many ways in the form of cream of various concentrations. Cream is a part of milk in which the fat is concentrated. Butter fat does

not mix with the non-fat portion or fraction of the milk in the manner in which other constituents do. The lactose and part of the ash constituents are found in true solution, while the protein is found partly in solution and partly in colloidal suspension in the water fraction of milk. The fat, on the other hand, is present in the non-fat material as a colloidal emulsion, that is, it does not dissolve in water but is held in the water as suspended globules; it is not held in the manner in which casein is held (93). The specific gravity of fat is somewhat lower, being about 0·93 at 15·5°C. (60°F.), than the non-fat portion of milk, the specific gravity of which is slightly higher than the value (1·032) for whole milk, or between 1·032 and 1·036.

Because fat does not mix with the non-fat portion of milk, it acts as an object submerged in it. Because of the lighter weight per unit volume of the fat, as compared to the non-fat part of the milk, the fat tends to rise to the surface of the whole milk. The force with which it rises follows a physical law which may be stated as follows: 'A body submerged in a liquid is buoyed up by a force equal to the weight of the liquid which it displaces'. Since fat weighs less per unit volume than the non-fat portion of the milk, the weight of a globule of fat is not as great as the weight of the non-fat material which that globule displaces when submerged. Each globule is, therefore, buoyed up by a force greater than its own weight; consequently it tends to rise to the surface.

As the fat globule moves through the non-fat portion of milk while rising, it encounters some interference. The extent of this interference is determined in part by the viscosity of the material through which it moves. The more viscous that material the more difficult it is for the fat globule to move through it, for it takes a greater force to move that material which lies immediately in front of the globule to one side in order that the globule may pass. The magnitude of the resistance a globule must overcome during its movement upwards is determined principally by the surface area of the particular fat globule involved. Fat globules assume a spherical form in whole milk. The area of a sphere varies with pi (3·1416) times the square of the diameter. The volume of the sphere varies with four-thirds pi times the cube of the radius. This means simply that an increase in the size or volume of a globule is accompanied by an increase in surface area, which, however, is proportionately

less than the increase in volume. This means that the resistance which a large globule meets is less per unit volume of fat than is true of a small globule. The force with which the small globule tends to rise is thereby more nearly offset by the resistance it encounters than is true of the large fat globule. Whatever the method of separation employed, therefore, there are always some small fat globules which remain in the non-fat portion of the milk, that is, in the skim milk. Furthermore, some globules rise faster than others.

Methods of Separating Milk

The different methods of separating milk are usually classified as gravity separation and mechanical separation.

Gravity Separation—Gravity separation is accomplished by placing whole milk in a container and allowing it to stand in a cool place until the butter fat accumulates at the surface. This layer is then carefully removed with a spoon or ladle. The portion removed is known as cream; the skim milk remains behind. The container in which milk is placed for this purpose may be shallow, making it necessary for the fat globules to rise only a short distance before reaching the surface; or the container may be deep, making it necessary for the fat to rise through a comparatively great distance before it reaches the surface. One method is about as effective in removing the fat as the other, provided sufficient time is allowed for the fat to rise. Because the fat rises through a shorter distance, less time is necessary for the formation of the cream layer in a shallow pan than in a deep pan.

Another procedure has been used in gravity separation known as the dilution method. In this method an equal quantity of water is mixed with milk to facilitate the separation of the fat. Two forces come into play in this procedure which may be noted. The specific gravity of water is 1·000 at 4°C. (21°F.) or 0·0800 at 15·5°C. (60°F.). The addition of water, therefore, would reduce the specific gravity of the whole milk-water mixture from that of whole milk toward that of water in proportion to the amount of water added. As a result the difference between the specific gravity of fat and that of the non-fat material in which it is then submerged becomes less. This tends to reduce the force with which the fat globule is buoyed upwards, making it less likely to rise. On the other hand, the addition of water

considerably reduces the viscosity of the non-fat material and thereby, other things being equal, reduces the resistance which a rising fat globule encounters. The reduction in resistance is greater than the reduction in the buoyancy so that the fat globules rise a little more easily with the addition of water than without. The sanitary considerations in the use of water, however, should preclude the use of this method of separation.

Mechanical Separation—Mechanical or centrifugal separation is accomplished by subjecting the milk to considerable centrifugal force by use of a cream separator. The principle on which the centrifugal separator operates can be expressed in terms of a second physical law. This law may be stated as follows: 'When two immiscible liquids are rotated about a common axis they tend to migrate, the one with the lower specific gravity towards the axis of rotation and the one with the higher specific gravity away from the axis of rotation.'

The centrifugal separator contains a unit known as the bowl. This bowl is so constructed that the whole milk is received at its centre, that is, at the axis on which it rotates. It flows into the bowl and is directed through a set of disks so arranged that the milk must pass between them in very thin films. The disks, being constructed at an angle, bring the butter fat or cream portion upwards as it moves towards the axis of rotation; the skim milk portion, as it moves outwards, is directed downwards until it reaches the periphery of the bowl. The skim then passes upwards along the inside surface of the bowl periphery and is removed as a separate level from that at which the cream is removed.

There are several factors which affect the efficiency with which the mechanical separator operates. The manufacturers of such machines always give careful instructions as to the operating conditions under which the machine may be expected to prove most efficient. Such instructions should always be carefully followed. Apart from the speed at which the separator should be operated, which is given by the manufacturer and frequently varies widely from one machine to another, there are some points that apply to all machines. The separator must be fixed firmly to a solid foundation and must be perfectly level. The operating speed must be uniform. The rate of inflow of milk into the separator bowl must be uniform and according to the specification of the manufacturers. The temperature of

the milk must be about body temperature, that is close to 100°F. The proper quantity of water should be used in flushing the bowl. These are the most important factors in the efficiency of operating the mechanical separator. Others which must not be overlooked, however, are the adjustment of the cream screw, the sanitation of the separating bowl and the condition of the milk.

The amount of cream varies with the speed of the separating bowl, other things being equal. A uniformly high speed gives a uniformly wide ratio of cream to skim milk, since the skim fraction, by reason of such increased centrifugal force, passes out of the bowl at an increase in rate greater than that of the cream fraction. This effects an increase in the fat percentage of the cream and, because of the exposure to a proportionately greater force, a lower fat test in the skim milk. The efficiency of separation consequently increases, although the economy of separation may be unsatisfactory. The cost of producing higher speeds and the greater rate at which they cause the mechanism of the separator to wear out must be considered. The lowered efficiency at lower speeds indicates the advisability of uniform speeds as recommended by the manufacturers. Hand operated separators are usually supposed to be operated at from 45 to 60 R.P.M. of the crank. The speed of the power operated machines must be adjusted by gears or pulleys between the power unit, usually an electric motor, and the separator. Separator bowls usually operate at 6000 R.P.M. (21).

The rate of inflow of milk into the separator is usually specified by the manufacturers. In smaller separators a float valve automatically adjusts this rate. The float must, however, be kept in good repair. If the rate of inflow exceeds that specified, the proportion of milk entering the bowl which passes through the cream outlet is increased, giving a lower fat percentage in the cream (31).

At body temperature the butter fat globules are liquid. In this form the fat flows most freely through the non-fat portion and can be most easily separated. Again the lower the temperature of the non-fat fraction of the milk the more viscous it becomes, hence the more resistance the fat globules encounter. Milk is most efficiently and economically separated, therefore, by mechanical separation at about 100°F. Higher temperatures may increase the efficiency of separation, but all things consi-

dered are not the most economical. Furthermore, as fat cools it becomes firm and hard. Fat in such a condition does not flow easily and may partially or entirely close the cream outlet.

Immediately after the milk has passed through the separator it should be followed by a quantity of clean warm water or fresh skim milk to displace the cream adhering to the different parts of the bowl. If any of the added skim or water is allowed to flow into the cream container the fat test of the cream will be lowered in proportion to the amount of skim or water involved. Sufficient flushing material should be used only to flush the bowl.

The separator bowl contains a special screw with which to adjust the proportion of the whole milk which is discharged as cream, or as skim milk. If this adjustment is fitted in the bowl opening through which the cream passes it is known as a cream screw, while if fitted to the skim milk opening it is called a skim milk screw ; the former is much more common. The cream screw is usually tubular, having a hole lengthwise through its centre through which the cream passes. It is fixed in the bowl so that it may be adjusted toward or away from the centre of the bowl. During operation of the separator the bowl is filled with milk in all degrees of separation. The more completely separated fractions, the cream and the skim milk, are farthest apart; the cream is near the centre of the bowl, the skim near the outside. The fat percentage of the successive vertical layers of milk in the bowl increases from the bowl shell inwards towards the centre. The centrifugal force to which different layers are subjected increase from the centre outwards toward the interior surface of the bowl shell. Each layer rotates at the same R.P.M., but the distance travelled by the milk in successive layers increases in proportion to pi or 3·1416 times the diameter. The centrifugal force does not increase in proportion to the velocity, but as the square of the velocity (31). As the cream screw is adjusted inwards its inner end, into which the cream enters, is shifted from layers subject to greater centrifugal force and containing less fat to layers subjected to less centrifugal force and containing more fat. The result is less cream containing a higher fat percentage. Adjustment outwards gives more cream with a lower fat content. The greater the proportion of the milk entering the bowl which passes out of the cream opening, the greater the quantity of cream but the lower its fat content.

Little difference in the efficiency or completeness of separation results, however, from readjustment of the cream screw, except for a tendency toward greater fat losses as the percentage of fat in the cream is increased.

Proper cleaning of the separator bowl immediately after it is used is of considerable importance for sanitary and mechanical reasons. The fact that milk comes into contact with the bowl parts, that milk solids consequently are present, necessitates careful cleaning and sterilization. This can only be done satisfactorily by completely dismantling the bowl, spouts, supply tank and regulating chamber, followed by washing and sterilizing the parts separately. The accumulation of milk solids in the separator occurs in three forms, *viz.*, in the cream portion near the centre of the bowl, in the slime adhering to the inner surface of the bowl shell and in the incompletely separated portion of the milk filling the body of the bowl. Bacteria cling to the fat globules and are swept out of the non-fat material as the fat is removed. Cream remaining in the separator, therefore, will have a high bacterial content. The mechanical separator acts somewhat as a clarifier, throwing coarse materials, such as body and blood cells, curd particles, dirt and clumps of micro-organisms, outwards. Such material accumulates as separator slime against the interior surface of the bowl shell. The presence of great numbers of bacteria and their required food materials makes the need for proper sanitation especially urgent.

Mechanically, the formation of slime may proceed to a point at which the passage of the skim may be partly stopped. Butter fat which has been allowed to remain in the bowl becomes hard on cooling, it may become dry due to evaporation of a part of the water of the non-fat material with which it is mixed, or the acidity which develops on standing may coagulate the milk protein in the cream layer. These changes in the cream, on standing, may result in complete stoppage of the cream outlet. Proper separator sanitation overcomes these difficulties.

The condition of the milk must be considered in reference to the efficiency of the operation of the separator. Milk which is old or milk which is slightly acid contains curd particles of varying sizes. Such curd particles, when passing through the separator, may accumulate at various points and eventually bring about stoppage of the bowl. This definitely interferes with efficient and proper separation of the milk.

Old machines which are out of balance, worn, bent, rusted or suffering from other mechanical conditions not conducive to smooth and efficient operation must be repaired or replaced to avoid losses of considerable quantities of butter fat in the skim milk.

The modern separator properly operated and cared for should produce skim milk containing not more than 0·01 to 0·03 per cent of fat (31).

Clarification

As centrifugation increases the tendency for fat to separate from milk serum, so also such force will facilitate separation of curd particles, dirt particles or bacterial cells from the milk. In the clarification of milk it is subjected to considerable centrifugal force in a machine known as the clarifier. Such a machine is constructed very much as a cream separator, except that the space between the outer edge of the disks contained in the bowl and the inner edge of the bowl shell is much greater than in a cream separator. This allows for the accumulation of large quantities of slime consisting of sediment and debris. Furthermore, the separating disk or false top always found in the bowl of a separator, is absent in the bowl of the clarifier. As milk passes through the clarifier bowl, which rotates at a very high speed, curd particles, dirt, bacterial cells and other debris or solid particles are thrown outwards, accumulating against the inner surface of the bowl shell. Milk then passes upwards and out of the bowl and is collected in a vat, a can or a pail.

Clarification is designed to remove debris from milk which is not removed by the usual straining or filtering. Large quantities of such material is removed from milk by this process. The bacterial plate count of the milk may not be reduced, however, in spite of very great numbers of bacteria being removed by clarification. This is explained by the fact that the bacterial plate count is a source count, not an individual cell count. Clarification breaks up clumps of bacterial cells contained in the milk with the result that, whereas great numbers of bacteria are removed, the number of bacterial clumps, each of which is the source of a colony observed in the plate count, is increased. The average clump, however, subsequent to clarification contains fewer bacteria than before so that the total number of bacterial cells contained in the milk is actually reduced.

Homogenization

The process of homogenization is designed to make milk, cream, ice cream mix or other liquid or semi-liquid dairy products more homogeneous. This is accomplished by grinding or breaking up the fat globules by passing the product through extremely fine orifices under high pressures. This is usually done at the temperature of pasteurization, *viz.*, between 145° and 165°F. Fat globules normally vary in size. Homogenization, if properly carried out, reduces them all to about one or two microns in diameter, depending upon the temperature and pressure used. This may increase the number of globules as much as 1200 times and their surface area 117 times (4). Solids other than fat are atomized and held in suspension (44).

The effects of the reduced size of the fat globule are many. As is explained elsewhere, the ease with which a fat globule rises depends upon its size and the resistance it must overcome, as determined by the viscosity of the non-fat material in which it is submerged. The fat globules in homogenized milk rise more slowly because they are smaller. Their greater surface area increases the friction at the fat/liquid interface per unit of fat, retarding their movement. The increased surface area of the fat absorbs more ions from the liquid phase thereby increasing the viscosity of the latter (93). In addition, therefore, to having a smoother texture (44) and a richer flavour and colour (93), homogenized milk products remain homogeneous or uniform much longer than normally because the fat does not rise, except under special circumstances. Homogenized cream will not easily whip; it will churn only with difficulty because the restricted motion of the globules prevents adequate concussion during agitation.

The quantity of additional ions absorbed at the fat/liquid interface after homogenization depends upon the degree of reduction in the average size of the globules or the degree of increase in total fat surface area. The greater the reduction in fat globule size the greater the increase in fat surface area and the larger the quantity of additional ions absorbed. As ion absorption increases, the viscosity of the liquid phase increases, whereas its curd tension decreases. This results from the presence in the liquid phase of fewer free salt ions, so important in curd

formation, as well as from the more numerous fat globules acting as points of weakness in the curd (93). Furthermore, the heat coagulation point of the homogenized product is lower (44).

In raw milk the action of lipase, a lipolytic enzyme, on the greater fat surface brings about more rapid development of a rancid flavour. Pasteurization destroys this enzyme, thereby delaying this fat breakdown (31).

Homogenized milk is easier to digest. Fat digestion is facilitated by the increased fat surface, the size of fat breakdown during digestion. The softer curd aids the action of digestive fluids on the protein, as is explained in Chapter IV.

Fat globule clumps or clusters act much like large globules in the speed with which they migrate through the liquid phase when acted upon by gravity or other forces. The clumping of fat globules is influenced by the number of globules; their movement, as a result of gravity or agitation; their temperature; and their electric charge, as influenced largely by the acidity of the liquid phase. Because of the higher fat content, clumping is more likely to occur in cream. The intensive agitation of fat which takes place during homogenization tends to prevent clumping; and the increased number of globules and their greater inactivity subsequently tends to discourage clumping. Clumping, however, is much greater as the fat content increases even with homogenization. The fat rises faster, therefore, in homogenized cream than in homogenized milk; also churning of homogenized cream, although very difficult in any case, becomes easier with higher fat concentrations. The fat globule membrane is more adhesive at low temperatures (93). Homogenization at high temperatures consequently reduces clumping. In fresh milk or cream the electric charge of each fat globule is the same; this is also true after the acidity of the serum has increased to a point greater than that at which casein is precipitated or at which coagulation takes place. This point, known as the iso-electric point of casein, is represented by a titratable acidity of between 0·51 per cent (47) and 0·65 per cent (32) or a pH of about 4·7. The charges of the globules are negative in the first instance and positive in the second (93). As the iso-electric point of casein is approached, however, unlike charges may occur in different globules, causing them to be attracted to each

other. Clumping may be expected to be greater in cream, therefore, from this cause, at an acidity of above 0·51 per cent. Clumping is greater with a single stage than with a double stage homogenizer.

Homogenizers commonly consist of a high pressure pump fitted with one or two special valves, known as homogenizer valves, just beyond the outlet valves of the pump. By means of a screw and a heavy spring, such pressures may be exerted on the homogenizer valve that forces up to 4000 pounds or more per square inch are necessary to force the milk past the homogenizer valve. As the pressure is increased on this valve the opening between it and its seat, through which the milk must pass, becomes smaller and the milk passes at a greater speed. As the milk passes the homogenizer valve it strikes the wall of the homogenizing chamber. The harder it strikes this wall the greater the extent to which the fat globules are shattered or reduced in size, hence the more efficient the homogenization.

Homogenization is used in the dairy to improve the body and texture of ice cream and certain types of cheese; it prevents churning of the fat, contained in the ice cream mix, during freezing. Homogenized milk in which the cream does not rise readily is also prepared for sale.

Washing

The importance of proper sanitation in the dairy cannot be overemphasized. The most important factor responsible for the deterioration of milk and milk products is bacterial contamination. Equipment and utensils are responsible for up to 80 per cent of the bacterial contamination of the products of the dairy. The most practical method of reducing contamination from this source is by means of proper sanitation. Until every surface of the equipment with which milk comes into contact is thoroughly sterilized it is not possible to produce milk of low bacterial count. Efficient sterilization is only possible if all milk solids have been removed previously by proper washing. The outside surfaces of equipment, the floors, walls, ceilings and the clothes of the employees must also be properly cleaned and kept clean to avoid their contributing directly or indirectly to pronounced bacterial contamination of dairy products.

Procedure for the Dairy or Creamery

The procedures to be followed in washing different pieces of equipment may vary slightly but all involve, fundamentally, the following steps:

1. rinse with cold water;
2. wash in hot washing powder solution, using a brush or cloth;
3. rinse with clean hot water;
4. sterilize by means of steam, hot water or chlorine solution;
5. dry by allowing complete drainage and, where possible, exposure to direct sunlight. *Never use a cloth for wiping utensils dry.*

The purpose of the initial cold water rinse is three-fold. Firstly, cold water is the cheapest agent employed in the washing of dairy utensils. There are quantities of free milk solids clinging to the surface of the utensils which can be removed simply by rinsing. The use of cold water is the most efficient and economical means of removing these excess solids. Secondly, milk proteins are coagulated by heat. If hot water were used at this time the milk proteins would tend to coagulate and become hardened, making them difficult to remove by the subsequent treatments. Thirdly, milk proteins are dehydrated, desiccated or dried by heat. The use of hot water at this time would cause the agglutination of milk solids, that is the proteins, on the surface of the utensil. Such material is removed only with considerable difficulty. As it is allowed to remain, which is very likely to happen to some extent at least, even with the greatest of care, milk stone forms. Milk stone may be removed only with relatively strong acids or alkalis which are injurious to the metals of which the utensils or equipment are made. Obviously, therefore, hot water must not be used at this stage.

The hot washing powder solution serves many purposes in the washing of equipment and is, therefore, the most important step, except for sterilization, of the whole procedure. The water dissolves the washing powder and serves as a carrier for it. The water should, for hand washing, be about 110° possibly up to 120°F. At this temperature it melts the butter fat, dissolves the lactose and soluble ash and assists the washing powder in softening the remaining solids, principally protein, which adhere

to the equipment. The washing powder is an alkali which neutralizes any milk acid present, softens the proteins and reacts with the liquid fat to emulsify it. If the alkali is strong enough its action on the fat will produce a kind of soap. The brush or cloth is used to remove, mechanically rather than chemically, the softened solid materials not otherwise removed from the surface of the container. It is imperative that some force be used to remove such materials, otherwise large quantities of them will remain and provide food materials for bacteria which may find their way into the equipment later or which may survive sterilization. Such solid materials offer a certain amount of protection to bacteria imbedded in them which may be sufficient to prevent their destruction during sterilization. The brush is especially useful for removing milk solids from corners which are not easily accessible. In certain mechanical can or bottle washers the necessary force for this purpose is supplied by pumping the washing powder solution into the cans or bottles under high pressure, rather than by use of brushes.

The clean hot water rinse further removes any milk solids that were loosened but not rinsed out by previous treatment; it also removes the major portion of any washing powder solution which may have failed to drain out. The high temperature of the water prevents any remaining fat from solidifying and adhering to the surface of the equipment.

The methods of sterilizing dairy equipment and utensils with steam, hot water or chlorine solutions are discussed elsewhere in this chapter. The purpose of this step may be restated, however, to emphasize its very great importance. Dairy equipment and utensils are sterilized to destroy all micro-organisms and their spores which may be present.

Many organisms cannot survive desiccation and very few can make use of various materials for food purposes unless they are available in solution. Thorough drying after sterilization greatly increases the effectiveness of the cleaning process by making it practically impossible for organisms, finding their way into the equipment after sterilization, to survive. Drying should be made possible by thorough drainage. The heat contained in equipment which is properly sterilized by means of steam or hot water will bring about rapid evaporation. This is also a help to complete and thorough drying.

Numerous materials may be used as washing powders. The most common of these are:

sodium carbonate (washing soda)	$Na_2CO_3 \cdot 10H_2O$
,, ,, (soda ash)	Na_2CO_3
sodium sesquicarbonate (natural soda)	$Na_2CO_3 \cdot 2NaHCO_3 \cdot 3H_2O$
sodium bicarbonate (baking soda)	$NaHCO_3$
tri-sodium phosphate	$Na_3PO_4 \cdot 12H_2O$
sodium hydroxide (caustic soda or soda lye)	$NaOH$

The carbonates of soda are most frequently used for washing purposes in the dairy as they are relatively safe to handle. Sodium hydroxide, on the other hand, is extremely caustic and is consequently dangerous unless handled carefully. It is commonly used in mechanical washers. Tri-sodium phosphate is a valuable cleaning material which is being used more widely every year. Its corrosive action on metals may be largely overcome by adding to it 5 per cent potassium dichromate. A good formula for a dairy cleaner for general use consists of a mixture of 100 pounds of soda ash plus 65 pounds of tri-sodium phosphate. The amount of cleaner to use will depend upon the nature and degree of hardness of the water, but will be about one pound to twenty gallons of water, or one part by weight of washing powder in 200 parts of water.

Soap and soap powder have no place in the sanitation of equipment surfaces with which milk comes into contact. Soap forms a film on the surface of equipment which can be rinsed off only with great difficulty; bacteria may be found in large numbers beneath such a film which offers them protection in several ways. Such films may also impart the undesirable flavour of soap in the products handled in the equipment subsequently. Soap is useful, however, in washing floors, walls, ceilings, clothes and the hands of the employees, but should not be used otherwise.

Procedure for the Village

The procedure commonly followed in washing dairy utensils in the villages is as follows:

1. rinse with cold water;
2. scour with mud or a paste made of wood ashes and water. Lemon or lime juice is sometimes used on brass to brighten it;
3. rinse with cold water;

4. place in the sun several hours, smoke thoroughly by inverting over an open fire or heat thoroughly over the fire.

The facilities available for proper sanitation of such utensils under village conditions are very limited. It is advisable, therefore, that rather than criticize this procedure, practicable suggestions might be made which would improve it as far as possible under the circumstances. The following suggestion is made, therefore, as an improved procedure of washing utensils in the village home. It is not recommended for use where circumstances permit the use of a better method. It must not be used in a dairy or creamery.

1. rinse with clean cold water;
2. scour with wood ash paste;
3. rinse with clean hot water;
4. sterilize by immersing in boiling hot water sufficiently long that the hand cannot be placed on the utensil anywhere without discomfort;
5. drain well;
6. place in the direct sun light several hours.

If wood ash is unavailable it is possible to substitute mud or fine sand, provided it is taken from an open field at least one furlong from the edge of the village and thoroughly roasted over a fire before it is used. A possible alternative method of sterilization would be to place a small quantity of water in the utensil, about a cup full, put a loose cover on the vessel and heat it over a fire until it is dry. This would steam the utensil satisfactorily and dry it at the same time.

Chemical Sterilization

Dairy equipment and utensils may be sterilized by chemical materials which are germicidal. Materials used for this purpose are usually chlorine compounds because they are not poisonous and do not ordinarily produce undesirable flavours in the products handled in the dairy. Chlorine in a free or loosely bound form is, however, not the most active element in giving germicidal properties to such compounds. The principal action of chlorine compounds for this purpose is a result of the presence of nascent, live or atomic oxygen. This substance, atomic oxygen, readily reacts with organic materials, of which the bacterial cell is composed, causing chemical changes to

occur. Such changes destroy the life of organisms. Some reaction does occur between the cell material and the chlorine if it is present as free or loosely combined chlorine, but the principal action is that of the oxygen. The strength required in chlorine solutions used for the purpose is expressed in terms of the number of parts of available chlorine in one million parts of the solution, usually written p. p. m. to refer to the parts per million of available chlorine. A suggestion has been made, but not yet adopted however, that the strength of such solutions be expressed as potential oxygen instead of available chlorine since the oxygen plays the more important part in the action of chlorine solution.

A large number of chlorine products are available on the market for sterilization purposes. They may be obtained in liquid or in powder form. These are usually hypochlorites or chloramine—T (93). Proper sanitation in the dairy requires the use of rather large quantities of chlorine solutions so that it may be found more economical to prepare the solution from basic materials purchased in quantity. The electrolysis of common salt in water solution will give hypochlorous acid.

A simple method, however, of preparing the necessary solution is by using 2 gallons of water, 14 ounces of bleaching powder or chlorinated lime, containing 30 per cent available chlorine, and 32 ounces of ordinary washing soda. The bleaching powder is made into a paste and mixed with a gallon of water, the washing soda is dissolved in a gallon of water, and the two solutions mixed. On standing a short time the insoluble material will settle out, leaving a clear supernatant stock solution that is used for sterilizing purposes. This solution will contain about 1·35 per cent available chlorine which will give a strength of 200 p p. m. available chlorine if mixed with water at the rate of 1 part of solution to 65 parts of water; this is roughly one pint in eight gallons. The solution should be kept in a closed container and in a dark place as the chlorine and oxygen may both pass off into the atmosphere and light dissipates the strength of the solution.

The germicidal property of a chlorine solution depends upon the strength of the solution, the speed with which the oxygen becomes available, the alkalinity of the solution and the quantity of organic material present other than that which constitutes the bodies of organisms. The amount of available

chlorine in the chlorinated lime used will determine the strength of the stock solution. Any variation in this respect should be cared for by altering the proportion of stock solution to water when preparing the final solution.

The organic chlorine preparation, available as chloramine—T, releases chlorine slowly. The result is it is less effective for sterilizing purposes unless sufficient time is allowed. The less alkaline the solution is the more rapidly hydrochlorous acid becomes available, consequently the more effective the solution.

A standard strength of 150 to 200 p. p. m. of available chlorine is sufficient for most purposes, although this concentration should never be allowed to fall below 100 p. p. m. This may happen if the solution is held too long before it is used, used too long or if the equipment or utensils on which it is used are not thoroughly cleaned beforehand. Any milk solids present are acted upon quite as readily as the bacterial cells; milk solids reduce the strength of the solution.

The equipment and utensils should be kept in contact with the chlorine solution for at least two minutes, whether they are immersed in the solution or it is pumped or sprayed on to the equipment. The chemistry of chlorine sterilizers is discussed in Chapter V.

CHAPTER IX

DAHÍ, GHEE AND BUTTER

Dahí

Dahí is India's most important milk product. Apart from the use that is made of *dahí* itself as a food or in certain food preparations, for which about 5·2 per cent of all milk is used, it is practically always an intermediate product in the manufacture of ghee for which 57 per cent of our milk is used (18). Its importance, therefore, arises not only because it is a milk product of commerce, but also because it influences the yield and quality of ghee. About 62 or 63 per cent of our milk, or roughly 15½ million tons annually, are used for *dahí*, the major portion of which is converted into *makkhan*, or village butter, and *maṭṭhá*, a by-product of the churning of *dahí*. The village butter is then heated to produce ghee.

The procedure for making *dahí* consists of the following steps, namely, selection, sterilization, cooling and inoculating of the milk and incubation.

The need for fresh milk of very good quality, if it must undergo heat treatment, particularly boiling, has been emphasized elsewhere. Boiling is a good test for the extent to which bacterial growth has taken place in milk, since acid production is usually the first consequence of the presence of bacteria in milk and acid reduces the heat coagulation point of milk. The sterilization of milk for *dahí* making usually involves boiling. If the quality of the milk is such that it cannot withstand that heat treatment it is obviously of no use in the manufacture of this milk product. The milk should be free of sediment as well as foreign flavours and odours which are themselves undesirable.

Whole milk or skim milk may be used. Skim milk makes an excellent quality of *dahí*, although it lacks a creamy flavour characteristic of that made of whole milk. The food value of *dahí* made from skim milk compares with that made from whole milk in the same way as skim milk and whole milk compare in

this respect. During the earlier part of the incubation period, before coagulation occurs, a large portion of the butter fat present in whole milk tends to rise, forming a cream layer at the top surface of the curd. This is not objectionable in *dahí* used for ghee making, but may be in that used for other purposes. *Dahí* made from whole milk, therefore, is in reality partially skimmed.

The milk should be heated to 190° to 200°F. for one hour or boiled for ten minutes, preferably in the container in which it is to be incubated. This treatment destroys all pathogenic and practically all non-pathogenic bacteria which may be present. Sterilizing the milk in the container in which it is to be incubated sterilizes that container at the same time. This container is, therefore, no longer a source of contamination; the danger of contamination of the sterile milk if it is transferred to another container for incubation is considerable. Having sterilized the milk, any fermentation which takes place in it thereafter will, except for possible contamination from other sources which every effort should be made to avoid, be a result of the action of only those organisms added in the starter with which it is inoculated.

After the milk has been sterilized it must be cooled to incubation temperature before it is inoculated. This temperature will vary with the culture that is to be used. For most purposes the inoculation temperature will be 70° to 72°F., for the common acid producing bacteria used in making *dahí* grow best within this range. For the first propagation of a dry or powder culture, however, it is advisable to use an incubation temperature of about 84° to 86°F. to stimulate the activity of the culture. Thereafter the usual incubation temperature is to be used. The incubation time and the amount of inoculum may vary from time to time, but good management of cultures requires that this temperature be charged only after everything else has failed to improve the culture which may be giving difficulty yet which shows no sign of being contaminated with undesirable organisms.

The inoculation of the milk consists of the addition of a small proportion of starter maintained for the purpose. The starter is a milk culture of the desired bacteria. For the preparation of *dahí* the bacteria are, for the most part, those which produce lactic acid in the milk. These are described in Chapter VI. The most common organisms involved are *Str. lactis* or *L. acidophilus*, while *L. bulgaricus* may be used sometimes. Certain

flavour or aroma producing organisms may be desirable in a *dahí* culture and undoubtedly are present very frequently, but this question has not yet received systematic study as to the flavours or odours desired and the bacteria required to produce them. Under conditions in which careful control is not exercised over the preparation and propagation of the starter, there is likely to be a mixture of organisms involved, but they must include a predominance of acid producers if *dahí* is to be produced. Sweet curdlers are rarely encountered and would not produce satisfactory *dahí* in any case. After the starter is added the inoculated milk is thoroughly mixed to assure uniform distribution of the bacteria contained in the starter.

The amount of starter to add will vary with the type of the starter, the nature and condition of the milk and the incubation time. The incubation temperature, as has been stated, will vary within narrow limits, depending upon the organisms involved and the nature of the starter, that is, whether it is liquid or dry. The proportion of starter may vary from 0·5 to 10 per cent of the milk to be inoculated, but is usually between two and five per cent. A good practice to follow is to vary the proportion of starter by multiples of two according to the condition of the *dahí* after the usual incubation time at the required temperature. If at the end of the regular incubation time the *dahí* has not properly set, it should be incubated another hour or so until it does set and the inoculum should be doubled when preparing the next batch; if at the end of the usual incubation time the *dahí* has set very firmly, has a strong acid flavour and is beginning to whey off, the rate of inoculation should be reduced to one half in the next batch.

If it is intended that the *dahí* be marketed in small individual containers the inoculated milk should be dipped into them just prior to incubation. Should the curd be dipped into such containers after coagulation is complete, it would be broken up and considerable wheying off, or separation of the whey from the curd, would result; neither of these is desirable. Such containers, if the inoculated milk is to be incubated in them, must be thoroughly sterilized beforehand lest they prove to be a source of contamination which would cause undesirable types of fermentation. It is, unfortunately, not practicable to boil the milk in a large number of such small containers. Then too, inoculation of the milk in one batch before dipping it assures more

uniform distribution of the starter which is necessary if satisfactory uniformity in the *dahí* is to be obtained.

As was stated earlier, the principal use for *dahí* is in the manufacture of ghee. A large volume of *dahí* is sold by *halwái* or shop keepers who sell milk, *dahí* and sweets. The usual practice, at least in certain parts of the country, in dispensing this milk product is to prepare it in large earthenware containers from which it is dipped as it is sold. Large quantities are prepared in the home for family use.

The keeping quality of *dahí*, like most milk products, is limited. Although it may keep longer than unprocessed milk, it will not keep indefinitely. It is well to prepare it in quantities that can be disposed of within 24 hours, unless refrigeration is available. This would make it possible to keep the product a while longer, but only another day or two. The sterilization of the milk before it is inoculated increases its keeping quality considerably, provided subsequent contamination or an undesirable starter flora does not produce defects in the finished product.

A common defect of *dahí* is a gassy condition. This results from contamination with yeasts or certain gas producing bacteria and is indicated by the presence of bubbles in the body and at the surface of the curd. Not only do the bubbles break up the curd somewhat, but the high acid which usually accompanies gas production, particularly when certain yeasts are involved, gives the product an intense acid flavour. Certain gas producing bacteria produce gas with a very undesirable odour. Gassy *dahí* may have a carbonated or soda water, possibly even alcoholic, flavour. As the acid content increases the degree of separation of the curd and the whey increases. Good quality fresh *dahí* does not whey off.

Dahí which has been incubated or held too long frequently develops excessive acid, giving it a strong acid flavour. This is commonly characteristic of old *dahí*. The surface of the curd may become mouldy due to atmospheric contamination. Not only may the appearance of such *dahí* be repulsive, but off flavours may quickly develop.

Insufficient inoculum, a short incubation time or too low an incubation temperature may result in a weak body, that is one which is very soft or only partially coagulated. The acidity of such curd is low and the flavour very mild. The use of adequate quantities of starter, sufficient incubation time and/or

incubation at the proper temperature will usually correct these defects. The body of *dahí* should be firm, yet not livery, that is, liver-like. It should break easily with a spoon or in the mouth, but should not be tough. Its texture should be smooth, fine and creamy, not coarse and flaky.

The acidity of *dahí* to be used for ghee making is probably the most important flavour consideration, provided it is otherwise clean and undesirable odours are not evident. It is possible that some consideration of the flavour developing properties of the starter involved, particularly flavours such as are desired in a good butter starter, may be worthwhile. This question, however, is yet to be studied. The flavour of *dahí* to be consumed as such or in food preparations, is primarily a question of acidity, apart from an otherwise clean flavour and odour.

Lassí

Lassí is a beverage made by mixing equal parts of *dahí* and water, with or without the addition of sugar, salt or fruit juices. This is an excellent drink for hot weather. It has a sharp acid flavour due to the acid contained in the *dahí*. Many people like it sweet so sugar is commonly added, while others like to salt it a little. The juice of any one of a variety of fruits may be added to give the *lassí* its characteristic flavour. Sugar and fruit juices are sometimes added together; but rarely, if ever, salt and fruit juices. The beverage is very refreshing if first cooled by the addition of ice.

Ṡríkhaṉḍ

Ṡríkhaṉḍ is prepared by draining *dahí* for 24 hours, without heating, to remove the whey. The curd is then mixed with sugar and forced through a cloth to break it up very finely. It may or may not then be coloured with saffron and flavoured. Nutmeg is sometimes used for flavouring this product of milk. If properly prepared, *ṡríkhaṉḍ* is a delicious addition to any regular meal.

Ghee

Of the milk produced in India, 57 per cent is converted into ghee (18). At the rate of 5 per cent outturn of ghee from milk this would amount to approximately 663,000 tons of ghee a year. The outturn is probably a little higher than this, how-

ever, considering the fact that so much of the milk from which it is made is buffalo milk containing about 7 per cent butter fat; it is probable that 6 per cent outturn is more accurate (22). If this is true, the production of ghee in India must be close to 800,000 tons annually.

Certain characteristics of ghee, that is, its keeping quality, and its high value per unit weight, make its production possible in areas which are a considerable distance from any large market. Ghee is made in certain areas, particularly the more remote areas, in greater quantities, therefore, than any other milk product. The principal ghee producing areas are in the Punjab and the United Provinces. It is estimated that at Etawah in the United Provinces alone between 50,000 and 60,000 maunds are marketed each year.

Ghee is usually made by what may be called the village method. Some attempts have been made, however, to employ other methods of manufacturing this product, but they are as yet not very popular.

Village Method

Whole milk is used in the village method of making ghee. This milk is first converted into *dahí* in the manner already described. The *dahí* is then churned to produce village butter or *makkhan* which is heated to evaporate the moisture and precipitate any milk solids-not-fat present. Ghee is the purified butter fat; it is sometimes referred to in other countries as butter oil or dry butter fat.

The sanitary standards followed in the making of ghee under village conditions are usually poor. The village butter is sometimes held for several days, even in the hot weather, before heating. During this time an extreme degree of fermentation and decay takes place very rapidly. This greatly reduces the quality of the butter for the purpose, giving ghee with undesirable flavours and a poor keeping quality. The sanitary condition of the containers in which the *dahí* is made and of the churn is usually very undesirable. They are consequently sources of contamination with innumerable types of organisms which bring about undesirable fermentations in the butter, especially if it is kept for any length of time.

The heating process is carried out in an open pan such as the *kaṛáhí*. Dung cakes are commonly used for fuel. This

fuel is undesirable for this purpose not alone because the manure from which it is made should be put on the fields, but because the very acrid odour of the smoke is readily absorbed by butter fat and gives rise to a smoky flavour in the ghee that may sometimes be very pronounced. The market quality of the ghee is reduced in proportion to the intensity of this defect, except that it is so commonly present that a very slight smoky flavour may be preferred by some people.

Village butter is heated to boiling but is boiled slowly lest it boil over and losses result. Moderate boiling should continue until the moisture present in the *makkhan* is completely evaporated. The boiling point of the fat is somewhat higher than that of the water. Boiling may take place in two stages. The first boiling that is noticed is due to the water contained in the butter. When this water is completely evaporated the boiling of the contents of the pan will cease until the temperature is further increased to the boiling point of the butter fat. It is unnecessary, however, to heat the ghee to that temperature. It should be heated only to between 118° and 123°C. (244·4° and 253·4°F.) at which the curd material, that is the milk solids-not-fat, becomes dry, slightly charred and settles out. Higher temperatures are liable to cause pronounced charring of the curd which may give a defective flavour to the ghee. They may also volatilize certain parts of the fat thereby causing losses. Prolonged heating at this stage has much the same effect.

The ghee is then removed from the fire and is either allowed to cool in the heating pan or is transferred to another container before cooling. The best method is to allow it to remain for a while, if possible, in that container in which it was heated, until the curd material has all settled out. The partially cooled ghee is then decanted or poured off the top into another container. The second container should be that in which the product is to be marketed.

Grain or crystal formation takes place during cooling. The rate of cooling will determine the final size of the grain, for the faster the ghee cools the smaller and more numerous the grains will be. This will depend upon other factors to some extent, however, such as the composition of the butter fat, which will determine the temperature at which it will solidify; and the amount of agitation during cooling. Crystallization is discussed in more detail in Chapter V.

Factory Butter Method

Ghee is also made, in small amounts, by heating factory butter, made by churning cream rather than whole milk. Although a certain amount of ripening of cream facilitates churning, its effect in cream is not so great as in whole milk; that is, *dahí* is rather easily churned as compared to fresh or unripened whole milk, whereas sweet or unripened cream will churn with little difficulty if the temperature is properly controlled. Because of the much lower water content in factory butter than in village butter, this method of ghee making involves much less heating than the village method. Village butter may contain as much as 25 to 35 per cent of water, with some samples containing as much as 60 per cent (22), while factory butter contains between 15 and 20 per cent of water. Should factory butter be made specifically for ghee making it would be advisable to reduce its water content somewhat. The curd content of this butter is likewise lower than that of village butter. Less moisture must be evaporated and, after it is driven off, less curd must be dried in factory than in village butter. The common method of obtaining cream for the making of factory butter is by use of the mechanical separator. The heating process in the conversion of factory butter into ghee is less expensive than that in the village method.

Cream Method

A third method of making ghee is by the heating of cream. It has been found that best results are obtained when cream of a very high fat content is used. The modern cream separator is so constructed that cream with up to 60 per cent of fat may be obtained; there are special attachments, however, for some separators which make it possible to obtain cream with as much as 80 per cent of fat. The higher the fat content of the cream the less water there will be to evaporate and the less curd there will be to dry. Cream of a high fat content, therefore, requires less heating than thin cream.

There are certain problems peculiar to this method of ghee making. Churning breaks down the fat globule membrane complex which is practically undisturbed by separation. Cream froths and foams more easily on heating, for this reason, than either village or factory butter. It is necessary, therefore, that cream be heated cautiously to avoid losses of fat which might

occur should the material boil over or should there be considerable sputtering of the cream during boiling. Because of this characteristic of cream and because of its higher water content, more prolonged boiling is needed than with butter. This need may be overcome to some extent if the cream is first heated sufficiently to bring about its separation into a fat layer at the top and a water layer at the bottom, with the latter being drained off before heating is continued. The fat is present in cream in the form of individual globules. Many of those are very small. Heating and agitation do not always wear away the fat globule membrane of the smallest globules sufficiently that they lose their identity. Draining away the lower water layer greatly minimizes losses due to boiling over or sputtering, but a reasonably large proportion of the fat, in the form of small globules, then passes off with this water layer. The yield of ghee by this method is usually less than by either of the other two. After the water contained in the cream is removed by evaporation, the higher curd content of the cream makes it necessary to heat the remaining material to a higher temperature or for a longer time to bring about complete drying and precipitation of the curd. The disadvantages of such a practice have been discussed under the village method of ghee making. After separating the cream it may be mixed with a quantity of plain water equal to the amount of the skim milk obtained and re-separated. This reduces the curd content of the cream to a considerable extent so that excessive heating may be avoided.

Ghee Quality

The quality of ghee is judged by its flavour and aroma, its colour, its keeping quality, its sediment content and its texture or grain size. Much of the ghee produced at the present time contains a dung cake smoke flavour and is slightly rancid. These defects are probably unnoticed by most people because they are so common in genuine ghee. The former arises from the use of cow dung cakes as fuel for heating the village butter. The latter is caused by the use of a contaminated starter, by the use of utensils which are not satisfactorily cleaned and by holding the *makkhan* as long as several days before converting it into ghee by heating. The particular type of decomposition of the butter fat which causes a rancid flavour takes place rapidly during the time the *makkhan* or village butter is held, particularly in the hot

weather. Should contamination occur shortly after the ghee is completed and should the moisture not have been completely removed during the heating process, bacterial growth which may produce flavour defects will take place.

Good ghee has a clean, oily, nutty flavour and odour, an odour characteristic of fresh, pure butter fat which has been heated. A charred flavour may result if the ghee is over-heated. Should ghee, or to a less extent the milk, *makkhan*, butter or cream from which it is made, be exposed to certain oily or volatile substances they will be readily absorbed. A flavour characteristic of the material involved is usually noticed in the final product. Most such flavours cannot be removed.

The milk of the zebu will give ghee with a slight yellow colour, whereas that of the buffalo will give a very white ghee. This variation is due to the carotene or yellow pigment content of the butter fat in the two kinds of milk. The feed the animals receive, their health and other factors, apart from species and breed differences, may influence the carotene content of the fat. Ghee made from factory butter containing added butter colour has a deeper yellow colour than what might be expected otherwise; it may have a lower keeping quality, depending upon the quality of the colour that was used. In the United Provinces, if not elsewhere as well, the sale of ghee made from artificially coloured butter is not allowed under the rules of the United Provinces Prevention of Adulteration Act of 1912 (13). A greenish colour may occur naturally in ghee made from buffalo milk or it may be produced by the addition of turmeric during heating. Ghee produced in certain areas from sheep and goat milk is known as *yellow ghee*. A peculiar golden-yellow colour and a low keeping quality characterize this ghee.

Ghee coming directly from the villages is referred to by the trade as raw ghee because it contains a proportion of water and usually a considerable amount of sediment. It must be reprocessed by heating; removal of the scum, which forms on the surface; and the sediment and curd by allowing it to settle out; followed by decanting off the ghee. Buyers of large quantities of ghee usually blend the ghee at the time the raw ghee is reprocessed. This is accomplished by mixing lots of different quality to give a blend of those used, thereby standardizing the quality of that obtained in a particular area.

The keeping quality of ghee depends primarily upon its moisture content. It is also determined by the extent of bacterial contamination subsequent to its manufacture, for the heating process virtually sterilizes the ghee. Ghee must be transferred from the heating pan to sterilized packing tins in a sanitary environment. The sooner these tins are then sealed the better, as aerial contamination must be combated at all times. Ghee that is made properly, that is, made from good quality raw products and which is dry, and which is placed in sterile packing tins and quickly sealed, should keep for a considerable length of time, possibly six months or more, regardless of the temperature conditions to which it may be exposed.

Certain types of fat deterioration of a purely chemical nature may occur, particularly if copper or iron salts are present and if the fat is exposed to air and sun light. All equipment in which ghee is made should contain as little exposed copper or iron as possible. Unless better materials, such as stainless steel, are available, the heating pan may be made from iron provided it is not allowed to rust and is thoroughly cleaned before it is used. Ghee should not be unnecessarily exposed to air or sun light. This can be avoided by sealing the ghee into tins as quickly as possible after it is made.

The sediment content of ghee is an indication of its quality. Good ghee is free of sediment. A small amount of sediment may be tolerated provided it is constituted of curd particles, not dirt or other debris. Dirty ghee has little market value.

Village Butter Milk or Maṭṭhá

A valuable by-product of ghee manufacturing is *maṭṭhạ́* or village butter milk. Approximately 75 per cent of the milk used in ghee making by the village method is available as butter milk. Because of the procedure used in the manufacture of ghee by that method the fat content of this butter milk is rather high, whereas the curd content is about equal to, possibly a little higher than, that of ordinary separated milk. It has a rather coarse curdy body and a fairly strong acid flavour; it is used exclusively as a food by members of the ghee producer's family. The production of this butter milk each year may be estimated as roughly 10,000,000 tons. About 2·3 pounds of *maṭṭhá* are equal in heat energy value to one pound of whole milk. The equivalent of about 4,000,000 tons of whole milk, therefore, is

available annually for food purposes in the form of village butter milk or *matthá*.

Butter

Two kinds of butter are made in India, village butter and factory butter. It is estimated that 1·71 per cent of the milk produced in the country is converted into factory butter, while village butter is an intermediate product in the manufacture of ghee by the village method for which 57 per cent of our milk is used (18). The outturn of factory butter is about 7 per cent of the milk used. On this basis nearly 430,000 tons of milk are used to produce about 30,000 tons of factory butter annually. The outturn of village butter varies considerably, but must be about 12 per cent or so. At this rate, approximately 1,700,000 tons of village butter or *makkhan* are produced annually from which 800,000 tons of ghee are made. The discussion will, for the most part, deal with factory butter since certain of the more important considerations in the making of village butter have been discussed under *dahí* and ghee making.

The butter fat test, the mechanical separator and the mechanical refrigerator have been important in the development of the butter making industry. In the more important butter making areas of India, namely, northern Bombay Presidency, western United Provinces and Bihar, cream or whole milk is now purchased on the basis of the butter fat content. This is determined by the Gerber test, described in Chapter V. Elsewhere, milk or cream is purchased for butter making on the basis either of volume or of butter outturn.

Wherever large quantities of butter are made mechanical refrigeration is employed. By means of ice or special cooling equipment the temperature of the cream, of the break water and of the wash water is adjusted as explained below. Very little butter is held in cold storage in this country. Butter that is to be held for an indefinite period of time is generally tinned. On the other hand, a large portion of our butter is produced without the aid of refrigeration even for cooling the cream. Such butter can be expected to be of a poorer quality and of a more variable composition.

Cream Procurement

Three methods of cream procurement are used. The small

manufacturer may obtain his supply from the milk produced by his own cows. Advantages of this method include the control it permits over the quality of the raw material. Producing one's own milk permits a degree of control in this respect that is not possible by any other means.

Where larger quantities of butter are made, this method has definite limitations. In this case cream may be purchased from persons who buy whole milk in village areas, separate it and dispose of the cream and skim milk separately. This method is used mainly by those butter manufacturers who are located in urban market areas and who make up to 25,000 pounds or so of butter a year. They commonly consider it more convenient, if not more economical, to purchase cream from others than to establish separating stations in the producing areas. The cream suppliers usually sell all their skim milk as such in the local market. It is not commonly converted into casein or other products.

A more common method of procuring cream, however, by the large butter manufacturer is by the purchase of whole milk in the producing areas. This milk is then separated in separators owned by the firm in what are called separating stations which are located near the source of the milk. The cream is then transported by train, motor or cycle to the butter factory. The skim is usually converted into casein at the separating station and sent to the factory where it is graded and sold. A small amount of the skim may be sold to those who supply the milk. The milk is purchased on the basis of its butter fat content.

Purchasing the milk or cream on the butter fat basis has certain advantages over purchase on the basis of the butter outturn. Firstly, less time is involved in determining how much fat has been received so that payment can be calculated more readily. The fat test requires only ten minutes or so to run and can be carried out by any skilled dairy worker who is given a little training. Secondly, the cost of churning is reduced since each lot of cream or milk supplied need not then be handled separately. This makes full churnings possible, whereas it would be necessary otherwise to churn more numerous batches of irregular size, depending upon the quantity involved in each lot; pasteurization, neutralization and ripening of each batch separately are then unnecessary. Finally, the amount received for his product by the milk or the cream supplier will not vary

with the final composition of the butter. Any variation in the moisture content of the butter will then rightly be the responsibility of the manufacturer.

Good quality butter cannot be made from poor cream. Attempts have been made in other countries to determine how to process poor cream so that butter of good quality might be produced. These attempts have regularly shown that the best assurance for the best possible quality in the butter involves the use of fresh, sweet pasteurized cream. The quality of cream for butter making purposes is judged by its acidity, flavour and odour and sediment content.

It is stated by an experienced buttermaker, who has had nearly ten years' experience in India making hundreds of pounds of butter daily, that the butter consumer of this country demands a low acid butter. He states that cream should never be churned with an acidity of greater than 0·50 per cent, while it is much better if it is below 0·15 per cent. He points out that the lack of refrigeration facilities, during transit and in retail shops, limits the keeping quality of butter and that, for this reason, it is necessary to make a better quality of butter so that it will maintain a marketable quality for a longer period. The acidity of cream can, within certain limits, be successfully reduced by neutralization. This does not remove other defects in the cream, however, so that excellent butter is not assured by neutralization. Apart from the acid flavour of high acid cream, there are innumerable other flavour defects which carry over, for the most part, into the butter regardless of how the cream may be treated to remove them. Pasteurization in the vacreator, described in Chapter VIII, is helpful but cannot be expected to make good cream out of bad.

Those flavour defects common to cream are old cream, putrid, smoky and possibly others which are of local importance. Causes for these defects have been discussed in Chapter VI as well as above, under ghee making.

In the preparation of cream for butter making one or more of several processes may be used. These are neutralization, pasteurization and ripening. In the industrial manufacture of butter each of these is employed. It is essential, for public health reasons, that the cream be pasteurized. Butter, like ice cream, would cease to exist as such if it were boiled, as milk is, in the home just before it is consumed. The heating of butter

is one method of making ghee. All cream must be pasteurized, therefore, to make it safe as a food for human use.

Neutralizing the Cream

The process of neutralizing cream consists of reducing its titratable acidity by the addition of an alkali. Whereas the term neutralization implies the complete reduction of acidity, this is not done when cream is neutralized. The acidity is reduced or standardized to a predetermined level, which is usually about the same as the normal acidity of milk, or about 0·12 to 0·18 per cent. The acidity may be reduced below this range under certain circumstances, but not commonly.

The procedure for neutralizing cream involves the following steps, namely, determination of the acidity of the cream, calculation of the amount of standard alkali solution required to reduce the acidity to a predetermined level, the addition of the neutralizing solution, and the determination of the acidity again as a check on the procedure. Three objects of neutralization are given by Hunziker (47), that is to avoid excessive losses of fat in the butter milk, to guard against the production of undesirable flavours in the butter and to improve the keeping quality of the butter. Coagulation of milk protein is aggravated by acidity and high temperatures. Should high acid cream be pasteurized, the protein fraction would be coagulated, forming curd particles which mechanically engulf some fat globules. As such particles pass into the butter milk they carry considerable fat with them, increasing the fat losses therein; on the other hand, as they remain in the butter they increase its curd content, the effect of which is detrimental to the keeping quality of the butter. As the curd content increases, the liability of the butter to rapid deterioration increases since the curd provides food material for proteolytic bacteria. Pasteurization of high acid cream is also liable to cause the occurrence of an oily flavour and a mealy body in the finished butter. Acid present in the non-fat fraction of butter during storage seems to facilitate certain undesirable chemical changes. Together with salt, in salted butter, it aids in dissolving the lecithin which, when in solution, is liable to the action of certain bacteria which produce a fish-like flavour in the butter. Neutralization is useful in preventing these defects.

The chemistry of neutralization and the procedure for de-

termining the titratable acidity of milk or cream are described in Chapter V. Either lime or soda may be used as a neutralizer. Lime contains calcium, a food mineral. It is a strong alkali, however, and requires considerable care in its addition if uniform neutralization is to be accomplished. Partial over-neutralization of the cream may result if lime is not added properly. Soda is a weaker alkali than lime and may therefore be easier to use. On reacting with acid, however, soda foams considerably as carbon dioxide gas is formed. Soda must be added slowly, particularly to high acid cream, to avoid causing the cream to foam up and run over.

The neutralizer should be added as a weak water solution of the alkali employed. It should never be added in a dry or powder form. The required amount is determined as explained in Chapter V. It must be added slowly so that it is quickly dissipated to prevent over-neutralization of a portion of the cream. It is best to add the alkali solution by sprinkling it over the surface of the cream while it is being agitated in the pasteurizing or forewarming vat. Excessive neutralization will give a neutralizer or possibly a soapy flavour in the butter. The neutralizer is added when the cream temperature is between 85° and 90°F. (47). Cream which is to be pasteurized by the hot-short or flash methods is usually neutralized in a special vat in which the temperature can be adjusted as required. When the holding method is employed, the cream may be neutralized within the temperature range indicated while the cream is being heated to pasteurization temperature. The pasteurization of milk or cream is discussed in Chapter VIII.

Ripening the Cream

Cream is ripened to improve the flavour and aroma and the keeping quality of the butter. The bacteriology of butter cultures is discussed in Chapter VI. As is stated above, cream should not be churned if the acidity is above 0·50 per cent. Hunziker, on the other hand, suggests 0·35 per cent as the maximum if fishiness is to be prevented in salted butter during prolonged storage (47). The lower the churning acidity the better the keeping quality of the butter. Ripening can, if properly carried out, considerably increase the intensity of the fine flavour and aroma, characteristic of excellent butter, without reducing its keeping quality. Natural ripening is possible but the degree

of acid, flavour and aroma development cannot be controlled by this method.

Churning Temperature

The temperature of butter fat changes more slowly than that of the non-fat fraction of milk or cream. The hardness of this fat will depend upon its composition and its temperature. If the temperature of the fat differs from that of the non-fat material present, the thermometer will show the average of the two when taking the temperature of cream. The thermometer reading will indicate the temperature of the fat only after the cream has been held sufficiently long at a particular temperature. This may take an hour or two.

The physical condition of the fat during the churning of the cream and the working of the butter is of considerable importance in determining the exhaustiveness of churning and the final moisture content of the butter. In order to assure the desired firmness of the fat the cream should be cooled to churning temperature and held there for at least two hours before it is churned. By this means it is possible to adjust the physical condition, that is, the firmness of the fat, within the limits required. During churning the movement of the cream about the churn generates a certain amount of heat due to friction. This heat is absorbed by the cream causing a slight increase in its temperature, and may increase that of the fat a few degrees. Wood, from which churns are usually made, is a good insulator. If the interior of the churn is properly cooled beforehand the churn will not be an important contributing factor to the increase of the cream temperature during churning. A high atmospheric temperature, common to a large part of India for most of the year, will bring about an increase of the cream temperature during churning. In order to assure the desired hardness of the fat for proper working, the temperature of the cream must be carefully adjusted before churning begins. The churning temperature will vary between 49°, possibly 48°F., in the hot weather to 51° or 52°F. in the winter.

Preparation of the Churn

The churn should always be thoroughly cleaned immediately after it is used. Just before being reused it should again be cleaned and cooled with cold or iced water. A common method

of cleaning the churn (47) involves rinsing it for several minutes with warm water, that is, at about 120°F.; washing it for 15 minutes with scalding hot water at 160° to 180°F. containing about 2 per cent of washing soda, the quantity of water required being sufficient to fill the churn about one-third full; and finally rinsing for 15 minutes or so with sufficient boiling hot water at about 200°F. to fill the churn one-third to one-half full. Immediately before it is to be used it should be rinsed for at least five minutes with water at 200°F. or higher; this is followed by rinsing for about 15 minutes with cold water at 50°F. or below in order to cool the churn. Instead of the boiling hot water rinse at this time, the cold water rinse may contain 100 p.p.m. chlorine to sterilize the interior of the churn before admitting the cream.

The Churning Operation

The butter fat globules vary in size from about 0·1 to 10·0 microns in diameter, averaging from 2·9 to 3·7 microns in zebu milk and 5·4 to 5·7 microns in buffalo milk (18). At the surface of each globule a peculiar physical condition exists which is commonly referred to as the fat globule membrane. Any molecule has two parts, one of which carries a positive electrical charge, the other a negative. At an interface such as the fat/non-fat interface of the fat globule and milk serum, chemical compounds tend to arrange themselves in such a manner that those parts or radicals which attract each other are nearest the interface. This orientation of molecules or accummulation of materials is so pronounced at this particular interface that it functions in many ways as a membrane, although it is not a true membrane.

During churning the friction and concussion of the globules against each other eventually wear down the thickness of this membrane so that it is weakened and the globules fuse easily. In confirmation of this theory of churning is the fact that whereas the lecithin is found almost exclusively in the fat globule membrane in milk or cream, it is found in a much greater concentration in the butter milk, in proportion to the amount of fat present, than in skim milk, whole milk or cream. This seems to result from the wearing away or rubbing off of the fat globule membrane as just described.

The fusing or joining of fat globules begins almost as soon

as churning begins. As churning progresses the cream increases in volume and viscosity until what is called the whipping stage is reached. Two things seem to be responsible for the whipping of the cream, namely, the increase in the fat globule masses, which increases the viscosity of the cream, and the incorporation of air into the body of the cream.

As the fat globule masses increase in size their surface area per unit volume decreases until finally a stage is reached when the emulsion breaks. At this stage, known as the breaking stage, the fat-in-skim milk emulsion ceases to exist. In its place appears a mass of butter granules immersed in buttermilk. Butter is considered a skim milk- or buttermilk-in-fat emulsion. As the butter breaks, the fat gathers rapidly into granules which engulf tiny droplets of butter milk. For best results, churning should be discontinued at that point at which the butter granules are about the size of *jwár* grains or small peas, that is, about one-eighth to one-fourth of an inch in diameter.

Following the breaking of the butter, the longer churning continues the larger the butter granules become. As their size increases, the amount of curd material they engulf will increase. Such material cannot be removed. Overchurning, therefore, increases the curd content of the final butter; this reduces its keeping quality. The finer the butter granules the more completely they can be washed to remove free or unengulfed curd. There is a minimum limit, however, to the butter granule size which must not be ignored. If the butter granules are so small that they pass through a cloth or wire gauze strainer while the butter milk is being removed, fat losses are greatly increased. This should be avoided by churning to a slightly larger size of butter granule. Overchurning also makes it difficult to control the moisture content of the finished butter.

On the appearance of the butter granules, when they are about one thirty-second of an inch in diameter, break water may or may not be added. It will be observed that a slight increase in the temperature of the churn contents has occurred by this time. Break water is added to reduce the temperature again to that at which churning began. At the same time, chilling the fat facilitates complete formation of butter granules which makes churning more exhaustive. This reduces fat losses in the buttermilk. The temperature of the break water should be about the same as the churning temperature, possibly a degree

or two lower. The quantity should be about one-third the volume of cream involved. Churning then continues until the butter granules are of the desired size.

The butter milk is drawn off through a cloth or wire gauze to recover any of the butter granules which pass off with it. All free buttermilk should be removed. This material is an excellent food for pigs or poultry and should not be discarded. It can be used for human food purposes although it is not greatly enjoyed by most people.

Washing the Butter

The butter granules are then washed. After removal of the buttermilk, a quantity of clean cold water is added and the churn is rotated for a short while. The quantity of wash water is about the same as the quantity of buttermilk removed. The wash water temperature will depend upon the season, the extent to which the butter fat temperature has increased during churning, the composition of the butter fat and the hardness desired in the butter granules; but it is usually about 2° or 3°F. below the churning temperature. After the addition of the wash water the churn is rotated a few times to assure the removal of all free buttermilk from the surface of the butter granules. The wash water is then drained off, care being taken to recover any butter which may pass off with it by draining it through a cloth or gauze. The washing is repeated until the final wash water is clear, indicating that the butter granules have been satisfactorily washed. The churn is finally drained thoroughly to remove any excess water when the butter is ready for working.

Working the Butter

Working consists of squeezing and pressing the butter granules together. This process accomplishes three things, namely, the butter mass becomes homogenous and the moisture and, where it is added, the salt are uniformly distributed. Underworking may give butter with a grainy or granular texture similar to that of the mass of butter granules; such butter will not be of uniform composition because of irregular distribution of moisture and salt; the colour will vary, being lightest where the moisture is greatest and darkest where the moisture is least. Underworking may be caused simply by stopping the process too soon, or it may be that the temperature of the butter granules

is too high or too low to make proper working possible. Warm fat is soft; such fat may become sticky and greasy before proper working can be accomplished; hard butter granules just cannot be worked together properly because of the resistance offered by cold fat. Overworking causes the butter to be sticky, greasy or salvy. It is usually a result of neglect on the part of the buttermaker, either of his churning temperature or of his working operation.

If the butter is to be salted, the required amount of salt is added during the working process. The amount of salt will vary with the market, but is generally one and one-half to two per cent; it does not usually exceed two and one-half per cent. The salt is added dry by sprinkling it over the surface of the butter during working. A good quality of clean salt must be used. The crystals of special grades of butter salt are flat and very thin so that they dissolve readily in the butter.

Moisture Control

The legal limit of moisture is 16 per cent in most parts of India, although in certain provinces 20 per cent is permitted. In either case moisture control is essential. By properly controlling the temperature of the fat during the churning operation the moisture can be controlled rather easily; a moisture content of 16 per cent may be obtained in this way with little difficulty. The food value of butter decreases rapidly as the moisture content increases. Increasing the moisture content of butter is a very convenient and easy means by which to reduce the cost of the product, but such a practice not only may make the persons involved liable to legal action, but is unethical and reduces the food value of the butter in proportion to the amount of moisture present. Moisture control is possible (1) by carefully controlling all temperatures, that is, of the churn, cream, break water, wash water and working table, unless the butter is worked inside the churn; (2) by draining off all excess buttermilk and wash water, and (3) by properly working the butter (see Appendix VIII).

Marketing the Butter

There are two principal types of package used in India for marketing butter. These are the tin and the parchment wrapped print. A very small quantity of butter is sold in waxed paper

cartons. Tins used for packing butter are made of tin plated iron sheets. To prevent direct contact of the butter with the interior surface of the tin it may be coated with shellac or the tin may be line with parchment liners before the butter is packed. The tins vary in size somewhat but are usually 4, 8, 16 or 32 ounces capacity. The tins are always of such size that they are completely filled About the body of the tin a paper is usually fixed which bears the name and trade mark of the manufacturer. Butter which is sold in packets is first printed in the desired shape and size by means of a small wooden mould and then wrapped in parchment paper. These prints are of several sizes, the most common being of 1, 2, 4, 8 or 16 ounces. The name and trade mark of the manufacturer are usually printed on the outside of the parchment wrapper. Butter which is sold in cartons is printed in the desired shape and size and wrapped with parchment paper as the packet butter is. The parchment paper, however, is usually plain or unprinted. This packet is then inserted into a waxed paper carton or box of the required size and on which the name and trade mark of the manufacturer appears. Cartons usually contain 4, 8 or 16 ounces of butter.

Butter is practically never held in cold storage in this country. That which is to be shipped some distance or which is handled by agents is usually tinned, whereas that which is sold locally or within a short distance of the butter factory is sold in packets or cartons. Butter may be shipped considerable distances and sold in packets, but special packing boxes are required in which ice may be placed during shipment.

Butter which contains the minimum of moisture and curd, which is made of fresh cream with low acidity and is slightly salted may be expected to keep for up to one week at temperatures at which it will not melt, that is below 75° to 80°F. Butter made of poor quality high acid cream and which contains a large amount of curd and moisture, from 1 to 1½ per cent of curd and 20 per cent or more of moisture, and which is unsalted may be expected to show pronounced deterioration within a day or two at the above temperatures. On the other hand, good quality butter which is kept under refrigeration at temperatures of -15° to -20°F. should keep for several months, although slow chemical deterioration which effects the flavour of such butter will occur. Practically no work has been done to study in a careful and systematic manner the keeping quality of tinned

butter. Considerable quantities of butter are put into tins in India and much of it is kept for considerable time, possibly several weeks, under a great range of temperature. Butter of good quality which is put into sterile tins in a sanitary environment should, if the tins are completely filled, keep for two or three months, possibly longer, at temperatures of up to 80°F.

Butter is tinned by completely filling sterile tins which are lined with vegetable parchment paper, preferably that which has been treated to destroy any bacteria, yeasts or moulds that may be clinging to it, or which are shellaced to prevent direct contact of the butter with the metal. The tins must be filled completely to exclude all air. The oxygen contained in any air which may remain in the tin will encourage deterioration of the butter during storage. The tins may be filled by putting the necessary butter into them by hand using wooden ladles or, preferably, the necessary butter may be measured by sections of a ribbon of butter as it feeds from a special cutting or printing machine such as the Doering butter cutter. The necessary length of the ribbon, which should be round and of slightly smaller diameter than the interior of the tin, may be placed into the tins, previously lined with parchment or shellaced, by the use of two wooden ladles. The tins are then closed by fixing the lids into place and then sealed by solder to assure no leakage of air into the tin.

CHAPTER X

KHOÁ, KHÍR, SÁR, MALÁÍ, RABAṚÍ, CHHENÁ AND SWEETS

Khoá

Khoá is a type of concentrated milk, made by boiling milk in an open pan or *kaṛáhí* to evaporate the moisture until only a solid dough-like mass remains. Almost 95 per cent of the water in the milk is removed in the process, consequently the total solids content of *khoá* is about 75 per cent, as compared to 13 to 16 per cent in the milk from which it is made. Whole milk is generally used, although it should be possible to make a fair quality of *khoá* from skim or separated milk. The former is preferred, however, because it gives a product with a smoother body and a more creamy flavour, which improve the quality of the sweets made from it.

The duration of boiling depends upon the quantity of milk involved and the rate of heat exchange.

Davies (22) states that not more than 2 seers of milk should be used at one time. This quantity will depend largely upon other factors. Boiling must be vigorous and continuous so that evaporation occurs as quickly as possible. Unless properly handled, however, the milk may boil over or become charred and stick to the bottom of the *kaṛáhí*. The former causes a considerable loss of milk, which is to be avoided for economic if not for other reasons; the latter gives the *khoá* a burnt or charred flavour and a brown colour, both of which reduce its quality, and greatly retard the rate of heat exchange by reducing the area of the bottom of the *kaṛáhí* over which this exchange takes place. Milk solids which concentrate on and adhere to the heated surface when charring occurs act as an insulator which largely prevents the passage of heat into the remaining milk. The quantity of milk must be adjusted according to the heating conditions in order to produce the desired quality of product.

The source of heat is usually a glowing fire of charcoal or of live coals of wood or coal. No smoke is desired as the milk may absorb it, causing an undesirable smoky flavour in the finished product. The fire must be uniform throughout the heating of each batch of milk and across its entire surface. The stove (*chúlá* or *aṅgeṭhí*) should be sufficiently wide that at least three-fourths of the bottom surface of the *kaṛáhí* is exposed to the fire during heating. No portion of the *kaṛáhí* should be exposed to the fire, however, which is not covered with milk either continuously, because of the level of the milk, or most of the time, because of continuous agitation causing the milk to be spread over the inside surface of the pan. Efficient utilization of the heat requires that the space between the bed of coals and the bottom of the *kaṛáhí* be closed on all sides, preferably with a well insulated material. An oven made of mud is commonly used for this purpose with the fire on a grate near the bottom and the *kaṛáhi* palced over the opening at the top. The free cross-passage of air between the fire and the *kaṛáhí* greatly reduces the effectiveness of the heat because of the losses that result. Since *khoá* is commonly made in small batches by the use of simple equipment, little if anything is known about its preparation in special dairy equipment by the use of steam. There appear to be no reasons, however, why this could not be done. Undoubtedly the evaporation of the moisture at temperatures, somewhat below that at which milk boils at atmospheric pressure, possible under a vacuum, would contribute greatly to the production of fine quality *khoá* by industrial methods.

The heat required to evaporate a quantity of water and the factors responsible for the efficiency of heat exchange are discussed in some detail in Chapter VIII. Special considerations in the heating of milk for *khoá* making are considered here.

The nature of the heat exchange that is required in the preparation of *khoá*, by the method so commonly used, involves the uniformity of the rate of exchange over the entire heating surface and/or the distribution of the heat over this surface as it passes through the thickness of the container well. The *kaṛáhí* is a shallow, round bottomed pan having two handles on it with which to lift it on or off the fire. A good *kaṛáhí* for this purpose is made of heavy iron with the inside surface smooth and highly polished by scouring with an abrasive such as fine sand. Con-

tinued use will keep this surface in good condition if rusting is prevented.

Mention is made of the need for the uniform application of heat over the bottom of the *karáhí* and of the need, for the purposes of heat exchange, for preventing the clinging of milk solids at any point to the inside surface of the pan. Should the heat intensity vary from place to place, the danger of burning and charring is increased. This usually takes place first over those areas exposed to the most heat. Once a layer of charred milk solids forms it serves as an insulator, preventing the free passage of heat into the milk which is so absolutely necessary if the water therein is to be rapidly evaporated.

The thickness of the *karáhí* and the composition of the material from which it is made influences the distribution of heat throughout the pan wall as it passes from the fire to the milk. Heat will pass more or less straight through a thin walled pan, with little distribution of the heat while doing so. In other words, the thinner the pan wall the more nearly will the heat intensity pattern on the milk side correspond to that on the fire side. The heat is deployed while passing through thick walled pans so that variations in the heat intensity pattern on the fire side disappear before reaching the milk side, consequently the heating of the milk over the heating surface is uniform in spite of minor variations in the application of the heat. It must be remembered, however, that the thicker the pan wall the greater the resistance it offers to the passage of heat so that, at least theoretically, this wall may be too thick. Uniform thickness is essential.

The ordinary *karáhí* available in the market is usually of sufficiently uniform composition and density that little practical difficulty is encountered, as a result of such variation, in the making of *khoá*. Some differences may be noted in these respects, however, between cast iron and rolled iron. It would be expected that these would differ considerably from such pans made from brass, aluminum, tin coated copper or possibly stainless steel in the speed with which heat passes through them and the extent to which it is dispersed or deployed while doing so. *Karáhiyán* of these materials, however, are rarely used, consequently they need no further consideration here.

Agitation of the milk is particularly important in making *khoá* because of the very great temperature differential involved,

that is, between the fire and the boiling milk. The purpose of agitation in *khoá* making, *viz.*, to prevent scorching, charring and boiling over of the milk, are discussed here. The common method of agitation or stirring of milk in this case is by use of a broad flexible metal stirring spatula known as a *khuntí*. It is essential that the blade of the *khuntí* be broad and flexible so that it may cover a large portion of the bottom of the *káṛáhí* at every stroke, scraping it free of any milk solids which may tend to adhere to it before scorching or charring takes place. The milk must be rapidly and continuously agitated by means of the *khuntí* throughout the heating process. To prevent the milk from boiling over at the beginning of the heating process it may be necessary to agitate it by pouring. Vigorous agitation causes a certain degree of emulsification of the fat which, as a result, becomes more uniformly distributed throughout the body of the finished product, giving a drier, yet more creamy *khoá*.

As heating progresses the contents of the pan will become more viscous or thick; its volume will be reduced by the removal of water by evaporation. Heating and stirring are to continue until the resulting mass is dough-like and represents about one-sixth to one-eighth of the volume of the milk used. In the final stages the pan may be removed from the fire; the heat in the pan wall may be sufficient to complete the process. The contents of the pan are gathered unto a single pat having the consistency of a soft dough. As it cools, however, it becomes harder. This is due to the hydration of the proteins of the milk. The whole process should take only 4 to 6 minutes (22).

The quality of the milk has considerable influence on the texture of the *khoá*. Fresh, low acid milk tolerates the prolonged boiling involved and thereby gives a very fine textured, smooth velvety *khoá*. As the developed acidity of the milk increases, the tendency toward coagulation during heating likewise increases. Poor quality milk gives a coarse curdy texture in the finished *khoá*. If the quality of the milk is very poor, complete coagulation of the milk casein may occur during heating before a sufficient degree of concentration is attained. In such cases the resulting *khoá* is of little value for the making of sweets, the primary use to which *khoá* is put.

The keeping quality of *khoá* depends entirely upon the degree of contamination and the extent to which it is exposed to conditions favourable to the growth of micro-organisms sub-

sequent to its manufacture. The process by which *khoá* is made gives a product which is sterile. *Khoá* made by *halawái* may be made into sweets immediately after it is prepared, thereby reducing the opportunity for any marked deterioration taking place. Under village conditions, however, the common practice is to wrap the *khoá* pats in green leaves in which it is transported to the nearest market. The leaves prove to be a source of considerable surface contamination with yeasts and moulds which, during transit and sale, find conditions ideal for rapid growth. Such *khoá* deteriorates rather rapidly so that it cannot be expected to keep more than four days (22). Wrapping in new, clean waxed or parchment paper would greatly reduce surface contamination and could, therefore, be expected to contribute to a better keeping quality. Such paper is not easily obtainable in the villages, hence a more practical possibility would be to handle *khoá* in covered earthenware containers which had been immersed several minutes in boiling water immediately before being used.

It is estimated that about five per cent of the milk produced in India is converted into *khoá* (40). It is made in only small quantities if at all elsewhere. It is, however, more commonly used as a base for the preparation of a great variety of milk sweets, such as those known as *peṛá*, *barafí* and *gulábjámun*. The sweet preparations from *khoá* are more common to our northern provinces than those made of *chhená*, the base for the sweets of Bengal.

Khoá may also be used in food preparation such as *do pyáz*.

Khír

In the manufacture of *khír*, milk is boiled in an open pan or *kaṛáhí* in the same manner as in the making of *khoá*. The boiling process, however, is continued only until the volume of the milk has been reduced to one-third or one-fourth of its original volume. Whole or cracked rice, certain other cereal products or vegetables may or may not be added before the heating begins. The product is usually sweetened. *Khír* is a rather viscous liquid very similar to condensed or evaporated milk, with or without added cereals or vegetables.

Khír is not ordinarily kept for any length of time; it is usually prepared for use in the home in quantities that will be readily consumed.

Over-heating or too rapid heating may produce carmelization, giving the product a slight yellow to brown colour, depending upon the degree of carmelization or carmel flavour development. It is practically impossible to avoid such a defect completely because of the heat treatment employed. But the nature of the heating and agitation during heating contributes considerably toward minimizing this defect.

The finished product may have a coarse texture because poor quality milk was used. Such milk is liable to coagulate on heating, as has already been discussed. There are occasions when the concentration is such that sugar crystals of appreciable size form during the cooling, unless cooling is rapid. This will depend partly upon the final concentration of sugar.

Khír is rarely manufactured for market purposes so that it is probably not a product for the dairy industry in a truly commercial sense. It is used in special dishes that are enjoyed by many people.

Sár

Sár consists fundamentally of only the skin or clotted cream layer that is repeatedly removed from the heated milk during the manufacture of *rabaṛí*. It more nearly corresponds to clotted cream, as manufactured in England, than any of the other milk products indigenous to India.

Malái

Malái is a term used rather generally to refer to cream or cream-like preparations such as *rabaṛí*, *sár* and cream that may be prepared by skimming or by separation. When used in reference to *rabaṛí* it usually refers to unsweetened *rabaṛí*.

Rabaṛí

Rabaṛí is another product of milk that is prepared by heating in a wide top open pan or *kaṛáhí*. In this case the milk is not boiled; but is heated to a temperature at which a certain amount of evaporation takes place and at which a skin may form on the surface. This is commonly referred to as a simmering temperature. Agitation interferes with the skin formation so that the milk is agitated as little as possible. Skin formation is encouraged in fact by fanning the surface of the milk during heating. Much of what is stated regarding the equipment for and technique of

heating milk in the preparation of *khoá* applies to *rabaṛí*, except that, to avoid boiling, a lower fire is used and the milk is stirred much less. The milk must likewise be of excellent quality for making this product if it is to endure the intense heating treatment it undergoes.

The skin which forms during heating is carefully removed from time to time by the use of a special dipper. This usually consists of bamboo or cane splinters. The *kaṛáhí* is only partially filled with milk. As successive skins are removed they are placed on the upper exposed inside edges of the pan, one upon the other. This process is continued until the remaining milk is about one-eighth the volume of that with which the process started. Sugar may or may not at this stage be dissolved in this milk at the rate of 2 ounces per seer of the original milk. The skins are then removed from the sides of the pan and immersed in the sweetened concentrated milk. This is followed by a short period of further evaporation. *Rabaṛí* consists, therefore, of a sweetened condensed whole milk containing the skins prepared as outlined here.

Rabaṛí is itself a sweet, as distinct from those made from *khoá* or *chhená*. It is considered a very great delicacy. It is usually prepared in small quantities either for sale or for personal use.

Chhená

Chhená is sometimes referred to as edible casein. It is prepared from milk, preferably but not exclusively that of the zebu, by precipitation of the protein. This is accomplished by the addition of acid, either as sour whey, citrus fruit juice or citric acid solution, while the milk is boiling. The *chhená* is then removed by draining off the whey. Soluble materials, principally the ash and lactose, of the milk pass off in the whey, while the protein—casein, lactalbumin (22)—and fat, held mechanically by the coagulated protein, largely constitute the *chhená*. This product of milk rather closely resembles certain types of uncured cheese, such as Neufchatel, made in western countries. Reference should be made to Chapter IV for a discussion of the chemical differences between the rennet and acid curds of milk.

The materials used for coagulating the milk may be either sour whey, citrus fruit juice or citric acid solution. Sour whey is prepared by incubating whey, obtained from the making of

either *chhená*, cheese or starter casein, for several hours until it reaches its maximum acidity. The fresh juices of limes or lemons are the best sources of citric acid among the citrus fruits and are for this reason more commonly used in the making of *chhená* than the juice of any other fruit of this group. The juice should be strained through a thin cloth before it is used. A citric acid solution is prepared by dissolving crystals of this acid in a little water.

The amount of coagulating agent required will depend upon the condition of the proteins in the separate lots of milk handled. As stated in Chapter V, the heat coagulation point of milk proteins varies with the acidity of the milk, the previous heat treatment, the age, health and feed of the cow and other factors. Of these, the first two are probably most important in influencing the amount of acid to add in preparing *chhená*. In no case, however, will this quantity vary more than just slightly because of the fact that milk proteins which fail to coagulate on boiling, a necessary step in the preparation of this milk product, are fairly heat stabile. According to Davies (22), the amount of acid required is that which will reduce the pH or milk from 6·6 to 4·6. This, he states, is equivalent to 0·6 per cent citric acid in milk at ordinary temperatures; at boiling temperature, with which one is dealing at the time the acid is added, it amounts to about 0·2 per cent of the milk, or between 10 and 15 grains of acid per pound of milk. The addition of a standard quantity of acid can best be controlled by use of a solution of citric acid, although citrus fruit juice or sour whey will serve just as well if added in quantities containing the required amount of acid. The acid of sour whey is not citric acid, as is true of the citrus fruit juices, but lactic acid.

The addition of an excess of the coagulating agent will give *chhená* with a sour flavour, while insufficient acid will cause only partial coagulation resulting in a soggy product and a milky whey. Insufficient acid will commonly give a slightly higher yield of *chhená*, but this is due to excessive moisture being retained by the curd. Actually a smaller proportion of the protein and fat of the milk will be contained in such *chhená*, the remainder being lost in the whey, giving it a milky colour. The average yield of *chhená* is about one-fifth or 20 per cent of the milk used.

The texture of *chhená* depends upon the nature of coagulation. Apart from the addition of the required amount of acid,

it is better that it be added while the milk is actually boiling on the fire. The practice of removing the boiling milk from the fire before the acid is added is sometimes followed. This produces a soggy product with a high moisture content, much as the addition of insufficient acid. *Chhená* of a fine texture with a smooth and velvety body is desired. Proper coagulation of good quality milk is essential if such *chhená* is to be obtained. Zebu milk produces better *chhená*, presumably, than buffalo milk, other things being equal.

Just after the coagulation is completed the whey may be drained off through a cloth. A rather dry product may be obtained by pressing the curd for a couple of hours or so after draining. Only the dry and firm *chhená* is used for frying while the softer and more moist creamy *chhená* may be used for the preparation of sweets. The latter is not fully satisfactory, however, for either purpose. *Chhená* will not keep well for more than a day or so, consequently it is necessary that it be prepared immediately before it is to be used.

Much less *chhená* than *khoá* is produced in the villages and transported to urban centres for marketing because of its comparatively poor keeping quality. *Chhená* tends to become sour rather rapidly, apart from the effects of surface contamination which are similar in type and intensity to those referred to in reference to *khoá*.

Two methods are given for the preparation of *chhená* (22 and 40); these are the family or small scale method and the commercial method. In the small scale method only about one seer of milk is handled at a time. The milk is brought to a boil, usually in much the manner already described for *khoá*. In this case, however, the heating need not be so intense since the milk is not to be boiled any longer than is necessary for the addition of the coagulating agent. The requirements as to the uniformity and kind of fire and the type of stove and *kaṛáhí* for the making of *khoá* apply in a general way in this case, as well. The instant the milk boils the necessary quantity of coagulating agent is added. The pan is removed from the fire as soon as coagulation is complete. The whey is then drained off. The *chhená* is gathered into a single pat in the draining cloth whether pressing is carried out or not.

In the commercial method larger quantities of milk may be handled. Sour whey is nearly always used for coagulating the

milk. In this method the sour whey may be added to the boiling milk, as in the small scale method, or boiling milk may be added to sour whey. The latter gives a higher yield of the soggy type of *chhená*, much as is obtained when coagulation is effected after the boiling milk is removed from the fire.

As has been stated above, a certain amount of *chhená* is used after frying, such as in making 'bara of chhana' or 'chhana and dhonka' (28). The majority of this product, however, is used for making sweets, particularly two types for which Bengal is famous, that is *rasagullá* and *sandeś*.

The food value of whey, obtained in the making of this milk product, is rather high since it contains most of the lactose, soluble ash constituents and water soluble vitamins, except those destroyed by heat, of the milk. For this reason it should not be discarded, but should be used as a beverage or in the preparation of liquid dishes such as soups.

Sweets

A great variety of sweets is made in India in which milk is used in one form or another. All sweets made from milk contain sugar, either as *guṛ* or refined sugar. Many of them contain a cereal product such as white flour; some contain vegetable marrow. A large number of products included in the term sweets is made from cereal or vegetable products and sugar, without milk. For those not especially familiar with them, it is not always easy to distinguish those made primarily with milk from the others. Certain sweets contain both milk and cereal or vegetable material. Although milk is frequently used in many European sweets, it does not usually form a basis for their manufacture so much as it does for many of those indigenous to India. The making of Indian sweets is an art. It is not presumed that it will become a science, and consequently an integral part of the dairy industry, in the immediate future. This discussion, however, will deal briefly with a few typical indigenous types of sweets made from *khoá* and *chhená*, for that is the principal use of these products, to which between 5 and 10 per cent of our milk is put. *Khír* and *rabaṛí* are themselves types of sweets. They have been discussed above.

Sweets made from Khoá

Two of the more common sweets made from *khoá* may be considered.

Barafí—Dry *khoá* is pulverized to form a powder. Passing it through a fine sieve will help. A syrup of sugar and water is prepared by boiling until of such consistency that the finished *barafí* hardens in six to eight minutes. A quantity of *khoá* powder sufficient to give a consistency of butter is then mixed into this syrup. This will be about two pounds of *khoá* for each eight ounces of sugar (40). The *khoá* is added slowly while the material is heated and stirred over a low fire. This is then poured into a flat pan to a depth of about one inch and allowed to cool. The product is then cut into cubes for serving.

Nuts, raisins, various colouring agents and/or essences may be added to give the different types of *barafí*, each of which usually has its own local name. The fineness to which the *khoá* is reduced before adding to the syrup, the concentration of the syrup and the rate of cooling each contributes to the texture of the finished product. The desired texture is fine and uniform. Rapid cooling tends to give a finer texture, as explained under the section on crystallization in Chapter V.

Guläbjámun—The following ingredients and instructions are recommended for *guläbjámun*, or rose apple (40). *Khoá* one pound, arrowroot flour two ounces, sugar two pounds and a quantity of ghee.

The *khoá* is pulverized and mixed with a quantity of the arrowroot flour into which a little ghee has been worked. This mass is then worked into a paste with the addition, if necessary, of a little water. A stock syrup of sugar and water is made, and a quantity of ghee is heated to a cooking temperature. A small ball of the *khoá*-arrowroot mixture is made and fried in the ghee. If it disintegrates during cooking, more arrowroot flour must be added. Since as little arrowroot flour as possible is to be added to get the balls to hold together, this test is worthwhile. It would be possible to add an excess of flour to begin with, but this is not desirable. When the right proportion of *khoá* and arrowroot flour is attained, the mixture is made into small balls, varying in size from about one to one and one-half inches in diameter. These are fried in the ghee and then transferred to the stock syrup while hot. While they have soaked up a good quantity of syrup they are ready for serving unless it is desired that they be rolled in granulated sugar first. Care is required in the heating to assure the balls being cooked uniformly and yet not

charred. They will finally attain a medium brown colour during the heating after all the moisture has been driven off.

Sweets made from Chhená

The most popular sweet made from *chhená* is undoubtedly the *rasagullá*. Another very delicious sweet made of this milk product is *sandeś*. These two varieties of sweets or *mitháiyán* are described very briefly.

Rasagullá—Two types of *rasagullá* are mentioned by Mrs. Halder (40). The first or common *rasagullá* contains *súji*, that is, coarse wheat flour, whereas the second or sponge *rasagullá* is plain. In the first case the *chhená* is mixed with *súji* and worked into balls, somewhat as if making *gulábjámun* from *khoá*. A sugar syrup is prepared by mixing sugar and water together and heating until threads about one to one and one-half inches long will form between two fingers when a little of the syrup is pressed between them and they are then drawn apart. The balls are boiled in this syrup for about 20 minutes. During this time the consistency of the syrup is maintained by the occasional addition of what water is necessary to replace that evaporated. The balls are then transferred to a stock syrup which is somewhat thicker than that in which the balls were boiled. The stock syrup should be at approximately the temperature of the boiling syrup when the balls are put into it. This avoids the danger of the balls breaking up, which may happen in a cold syrup. They are allowed to cool in this syrup in which they are served.

This sweet is prepared in a variety of sizes, shapes and colours. The different varieties are made to resemble many of the fruits and may be given the name of the fruit concerned, such as *ám rasagullá* which resembles the mango both in shape and colour.

Sandeś—This sweet may be prepared by either the sugar method or the syrup method (40), of which the first seems to give the best quality of product. A slightly more moist *chhená* is used in the first to facilitate the dissolving of the sugar, while in the second method the *chhená* is pressed out until it is very dry and the sugar is moistened with water before it is used. The greater the proportion of *chhená* to sugar the better the quality produced by either method. Best results are obtained, we are told, by using two pounds of *chhená* to eight ounces of sugar.

The *chhená* is ground into a fine powder, mixed with the

sugar and heated over a low fire until the mass draws away from the edge of the pan. Continuous agitation is necessary during cooking to prevent scorching. The mass is then placed in a shallow pan, much as indicated for *barafí*, and allowed to cool before it is ready for serving. In the syrup method, the syrup is prepared and the powdered *chhená* is added to it. The rest of the process is fundamentally the same as for the sugar method.

Sandeś is commonly moulded into different shapes by hand or by the use of wooden moulds. Any shape may be used, such as that of a fish, fruit, flower or nut; the sweet may, however, be cut into cubes only. It may be flavoured or coloured as desired.

CHAPTER XI

CASEIN, CHEESE, ICE CREAM, *KULAFÍ*, EVAPORATED AND CONDENSED MILK AND DRIED MILK

Casein

The quantity of all milk and milk products available is far too small to meet the nutritional needs of our people. For this reason it is imperative that every ounce of milk be used for human consumption in one form or another. No milk should be converted into a product that is not edible or which is of no use as a human food, if this can be avoided. Skim milk is a very bulky material because of its high water content. Such a product cannot be economically transported very far before the transportation costs become excessive. Like whole milk, skim milk is highly perishable and must be utilized immediately if spoilage is to be avoided. Very slight acid development causes skim milk to coagulate under the heat treatments used in the making of condensed or dried milk and large quantities of skim must be assembled in a particular place to make the manufacture of these products economical. There is practically no market for *dahí*, *khoá* or cheese made from skim milk, although it is urged that such a market be developed wherever possible. Where pig and poultry products have a market, skim milk may be utilized as an animal food in producing these products which are used for human food purposes.

Large quantities of skim or separated milk are available in the butter producing areas of India. These quantities are in excess of what is, or can possibly be, consumed in the liquid state locally. Since much of this product can neither be transported to a market, not utilized economically in making an edible product, such as skim milk powder, condensed skim milk, *dahí*, *khoá* or cheese, and since it is not commonly fed to pigs or chickens which are in turn sold for human consumption, its conversion into casein is sometimes justifiable.

Two types of casein are made, namely, rennet casein and acid casein. Their methods of manufacture, final composition and industrial uses differ somewhat. Skim milk is used for

either type. The presence of fat, even in small quantities, in the finished casein greatly reduces its keeping quality and its usefulness for industrial purposes. For this reason it is well to reseparate the skim before it is used. This gives a slightly lower fat content than is obtained otherwise. The milk must be clean and free from sediment which may cause a granular or discoloured final product that will receive a lower market price. The bacterial content of the milk must be as low as possible, although acid producing bacteria are not so obnoxious as those which are proteolytic. These latter organisms are especially undesirable for during both the manufacture and storage of the casein they may be responsible for considerable deterioration in this product. The yield of dried casein of either type is approximately three per cent. Reference should be made to Sutermeister and Browne (96) and Hadert (39) for details of casein manufacture and its uses which are not included here.

Rennet Casein

Rennet casein is made by coagulating the milk by means of rennet, the action of which is discussed in Chapter VIII. The milk should be warmed to about 96°F. and 4 ounces of rennet, or its equivalent, added to 100 gallons of milk. The quantity of rennet required will depend upon the acidity of the milk, the strength of the rennet and the temperature at which the milk is set. It should be sufficient, however, to give coagulation in 15 to 20 minutes. Liquid rennet should be diluted, as in the making of cheese, with 40 to 50 times its volume of water; the powdered or tablet rennet should be prepared in such a manner as to be of similar strength when added to the milk.

After coagulation has occurred the curd is broken into small pieces of uniform size. This may be done by means of special knives like those used in cheese making. The curd particles should not be too fine, however, for losses in the whey may increase as a result. The curd is then heated to 130° to 150°F. to destroy the rennin, the enzyme of rennet. After allowing the curd to settle for 10 minutes or so the whey is removed. When the whey has been removed the curd is washed several times with fresh clean water at 80° to 90°F. The wash water is then removed, the curd is drained and pressed from one to several hours, shredded and dried.

The drying of casein should be done artificially at 110° to

150°F. It is not advisable to dry casein in the sun for the rays of the sun produce chemical changes in the product which bring about discolouration (22). There is also the danger of dirt, dust and insects getting into the product which reduce its quality. Sun drying is possible, however, and is commonly employed in the manufacture of small quantities of casein.

After the casein is dried it should be ground and graded for marketing. The different industrial uses to which casein is put provides a market for various grades of casein. Grinding and grading the product before marketing makes it possible to take advantage of a better market for certain special grades than for a general grade.

The casein may have several defects, such as excessive moisture and fat, a disagreeable odour, discolouration and a high dirt content. The use of good quality reseparated skim milk, artificial drying and proper storage facilities aid in preventing colour defects. Casein made from buffalo milk may have a blue-grey colour. Though discriminated against to some extent, this is not a defect which it seems can be overcome. A dark brown colour may result from the presence of certain types of dirt, but usually is caused by insufficient drying. A high fat content, that is greater than one per cent in the finished casein, may also be the cause of a brown or yellowish colour. The presence of various kinds of dirt results in the appearance of different colours, usually yellowish brown, grey or black. Such defects can be avoided by the careful processing of clean milk.

Casein may develop offensive odours, particularly if the original milk was highly contaminated with proteolytic bacteria or if the casein is stored at high temperatures, especially if drying was not complete before storage. Casein with a moisture content greater than 5 per cent will deteriorate faster in storage than that with less moisture.

There is little demand in India for casein for the manufacture of plastics. Most of the casein consumed domestically is used for paints, glues and, to a limited extent, paper and cloth sizing. Rennet casein is not satisfactory for glue and paint manufacture because of its high ash content.

Acid Casein

Acid casein is prepared by the natural souring method, by

the addition of lactic acid either as a solution of the acid or as sour whey, or by adding other kinds of dilute acids.

In the first case, skim milk is heated to about 70°F. and a starter is added. The temperature is maintained for several hours until a firm curd appears. The curd is then cut, as suggested under rennet casein, and cooked to separate the whey. The cooking temperature will vary with the characteristics of the curd. If this temperature is too high a tough rubbery curd may result. The cooking temperature is maintained only briefly before the whey is drawn off. As the whey is removed the curd is piled so as to facilitate complete drainage. It is then washed carefully to remove as much of the whey as possible so that the lactose content of the finished curd will be reduced to a minimum. It is then pressed overnight, shredded and dried at 130°F., preferably by artificial means.

The naturally soured acid casein usually lacks uniformity as a result of variation in the amount of acid present. It is liable also to be highly contaminated with proteolytic bacteria entering through the starter or from the air during the several hours the milk is held while ripening. As has been explained, proteolytic contamination is very undesirable because of the offensive odour and the discolouration that is produced during the decomposition of the casein that results. The high albumen content of naturally soured casein is not desirable.

Casein that is made by the addition of lactic acid is prepared in much the same manner as other types of casein except for the method of coagulation. The curd produced is an acid curd, similar to the naturally soured casein curd. The lactic acid may be supplied in a water solution of pure lactic acid, obtainable from a chemist's shop, or in the whey from the previous day's batch. Whey for this purpose is held at a temperature at which lactic acid formation is encouraged until an acidity of around 0·8 to 0·9 per cent is obtained. Such whey may then be used for coagulating the milk, sufficient being added to bring about rapid coagulation. This method offers a means of utilizing at least a part of the whey produced as a by-product of casein manufacture. Two to ten per cent of the whey will bring about coagulation in three to six hours at 100° to 106°F. (84). More uniform curd is obtained if coagulation is brought about by the addition of lactic acid in either of these two forms than if the curd is produced by the natural souring method.

The procedure subsequent to coagulation is the same as for the naturally soured product. Heating may be brought about in either case by passing live steam through the curd in the whey or by adding hot water. The curd is pressed from one to three hours, shredded and dried. The ash content of this type of casein is slightly higher than that produced by the natural souring method (21); the additional time involved in acid formation, consequently in coagulation, in the latter method allows for the passage of greater quantities of ash into the whey which is drawn off.

Acids other than lactic acid may be used in the making of casein, giving a product very similar, for most purposes, to that produced by the natural souring method or by the addition of lactic acid. This type of casein is frequently called the *grain curd type*. Hydrochloric, sulphuric, phosphoric or certain other acids may be employed.

Whichever acid is used, sufficient is added to the milk at 95°F. to give a pH, using methyl red as an indicator, of 4·6(4). The acid must always be added in a dilute form. Rapid coagulation gives a curd with a relatively high ash content of two to three per cent in the finished product (21). The addition of a slight excess of acid, or sufficient to reduce the pH to a little less than 4·6, followed by the addition of a quantity of alkali to bring the pH back to 4·6, gives a product with somewhat less ash than is otherwise possible (21). Thorough and rapid washing aids in a reduction of the acid as well as of the ash in the finished product. As has been stated, the lower the ash the better the casein for glue and paint manufacture.

Cheese

Cheese is an important milk product in certain European countries. Except for the last few years, very little cheese was made in India; only about 10,000 hundredweights of all kinds were imported (113). Recently, however, quantities of the cheddar type of cheese have been produced in the Punjab, Bombay and United Provinces.

Several factors have contributed to the lack of importance of this product in India. One was a popular belief that cheese could not be produced under the conditions existing here. The quality of cheese that is now being made, however, has proved

the fallacy of that contention. There is little doubt that the manufacture of good quality cheese is now well established.

Another factor which has been important in limiting the quality, if not also the quantity, of domestic cheese is the quality of milk generally available. Cheese making requires an especially high quality of milk, much as is required for *khoá* and *chhená*, but in large quantities than are ordinarily used in their manufacture. The difficulty of getting the necessary quality of milk is familiar to those who have made even small amounts of *khoá*, for example. For the economic operation of a cheese factory, fresh milk is required in volumes which in the past, and to a large extent at the present, have been unavailable in any one area.

A third reason for the manufacture of so little cheese in India is the fact that an enzyme known as rennin is required in making most types of this milk product. A rennin preparation, called rennet, is prepared, as indicated in Chapter VIII, from the stomachs of young calves. Being an animal product, rennet is not consumed by a large portion of our population. The objection to the use of cheese for this reason is being overcome as investigations reveal the availability of enzymes of vegetable origin that will substitute satisfactorily for the more common animal product. Vegetable preparations which coagulate milk are made from the berries of *Withania coagulans* (82 and 59) and from *Carica papaya* which is the common papaya (75).

Inadequate refrigeration facilities have also contributed, no doubt, to the slow development of the cheese making industry of India. The temperatures necessary for the curing of cheese are not possible by natural means in a climate common to the greater part of this country. The required temperatures may be available in certain of the hill areas, but so little milk may be obtained there that cheese making cannot be profitable. As mechanical refrigeration has been introduced on a wider scale, so the manufacture of cheese, as in the manufacture and handling of many other milk products, has developed. With further development in the availability of efficient mechanical refrigeration, cheese manufacture, like that of ice cream, can be expected to become even more important in India's dairy industry than it now is.

There are 18 distinct varieties of cheese which are known by several hundred different local names (29). These different

kinds of cheese can all be classified in three groups. These are soft cheese, such as cream cheese or Surati cheese; semi-hard or hard cheese, such as Cheddar or Edam; and grating cheese, such as certain ones made particularly in Italy. With the exception of some varieties of soft cheese, such as a popular skim milk cheese, called cottage cheese, made in the United States with or without rennet, most cheese is made by coagulating the milk by use of rennet or a combination of rennet and starter. The curd is then cut into small cubes by means of special knives to facilitate cooking and drainage. These curd cubes are slightly cooked and the whey is drained off. The curd may or may not be treated by holding at definite temperatures at which cheddaring takes place; it is then milled, salted and pressed into prints of different size. Cheese may be utilized fresh or after being cured by the action of bacteria or moulds. Yeasts sometimes play a part, but there are no special varieties of cheese which depend for the development of their flavour and odour entirely upon the action of yeasts. A common example of a type that is cured by the action of bacteria is Cheddar cheese, which will be discussed in more detail later. An example of that cured by the action of moulds is Roquefort, a French cheese made from the milk of the sheep.

Rennet may be used to coagulate the milk in the manufacture of cream cheese, or acid alone may be employed. Usually the acid is developed in the milk by the addition of a starter, followed by incubation at a fixed temperature until coagulation occurs.

Milk which is highly contaminated with the usual types of bacteria is not desirable for cheese making. Although milk may be pasteurized to destroy most of the organisms present, the contamination has usually already produced chemical and physical changes in the milk which reduce its quality for cheese making purposes. Milk with the lowest possible bacterial count, therefore, is required; especially it is desirable to have milk which is free of gas producing organisms. Many such organisms are soil or water borne and frequently produce spores which survive pasteurization only to be revived by the temperature employed during the cheese making process. Should this occur, gas would be produced. This would greatly interfere with the processing of the curd and the growth of such organisms produces gas holes and possible off flavours in the cured cheese.

Yeasts are especially undesirable in milk that is to be used for cheese making. Although yeasts can be destroyed by pasteurization, their entrance subsequently is a factor that must not be overlooked. Milk that is produced by animals which are diseased or whose secretory tissue is diseased is not satisfactory for cheese making since its chemical and physical properties may have been so altered that it does not respond normally to the treatment to which it is subjected in the making of cheese. The experienced cheese maker can tell readily, whether the milk he is using contains even a portion from diseased udders. Milk with off flavours and odours must likewise be avoided for such characteristics will appear in the finished cheese, reducing its sale value in proportion to their intensity.

In the manufacture of cheese in which rennet is used the presence of acid is necessary to facilitate rennet action. Cultures of lactic acid bacteria are consequently necessary. Starters for making Cheddar cheese should also contain organisms that facilitate protein decomposition during storage, such as *Str. liquefaciens*. The addition, therefore, of special starters or milk cultures containing specific bacteria is essential to the manufacture of many kinds of cheese.

Cheddar Cheese

Ripening milk at the beginning of the cheese making process brings about an increase in the acidity. The purpose of lactic acid at this time is three-fold, according to Van Slyke and Price (106) : 1. it makes possible proper rennet coagulation, 2. it represses the growth of undesirable organisms in milk; and 3. it facilitates the proper control of moisture in the curd and the texture of the finished product. The amount of starter to add and the time interval between the addition of the starter and the addition of the rennet depends upon the acidity of the milk, the acidity of the starter, the temperature of the milk and the rate of acid development after the addition of the starter. The titratable acidity of the milk at the time of adding the rennet should be slightly higher than the normal acidity of the milk, or around 0·18 to 0·21 per cent. Milk with a high initial acidity may not require the addition of a starter to assure proper action of the rennet. Some starter is necessary, however, in order that the curing of the cheese proceed satisfactorily. The addition of starter to milk of poor quality may give rise to certain difficul-

ties in the manufacturing process. The action of the rennet is not complete at the time coagulation occurs, but continues throughout the curing period. This action is particularly pronounced during the processing of the milk and of the curd before it is pressed. For development of the proper body in the curd, the acidity of the milk and, after coagulation, the whey must not proceed so far that it may interfere with the action of the rennet. The addition of that proportion of starter needed to assure the presence of the necessary population of proteolytic organisms to give the desired degree of protein breakdown during curing may, if the milk is of poor quality with high acidity, supply an excess of acid-producing bacteria. The temperature of the milk should be about 70°F. when adding the starter.

The functions of rennet in cheese making have been discussed in Chapter VIII. The quantity of rennet to add will depend upon the acidity of the milk, the temperature of the milk, the strength of the rennet preparation and possibly other factors. For the standard liquid rennet preparations two to four ounces for each 1000 pounds of milk may be used. The rennet must be diluted with about 40 times its volume of pure cold water to assure uniform distribution in the milk. The quantity of rennet, whether liquid or desiccated rennet, should be sufficient to bring about coagulation in about 30 minutes. The milk should be heated to about 85°F. before the rennet is added.

When the milk is properly set the curd is cut by means of special knives so designed that cube-shaped particles of a uniform size are obtained, usually three-eighths to one-half an inch on a side. A common test for determining when the curd should be cut is made by inserting the index finger into the curd in a diagonal position. The finger is then removed by raising it vertically. If the curd breaks ahead of the finger and leaves the finger clean, it is ready for cutting. Cutting too soon may increase the fat loss in the whey; cutting too late may cause a hard dry cheese.

As soon as the curd is cut it must be agitated to prevent settling as well as to assure uniform heating and drainage of each curd particle. If such curd is allowed to settle out, a thick mat will form; satisfactory heating is then impossible. Agitation must be very gentle at first for the curd particles are extremely soft and must not be broken up. They become harder, however, during cooking so that agitation may, although this is

unnecessary, be more vigorous later on. Agitation a few minutes before cooking commences is required.

The maximum cooking temperature should not be more than 100° to 105°F. The temperature may be increased during cooking about 2°F. each five minutes if lactic acid formation progresses satisfactorily, otherwise this rate will vary with the acid development and change in the firmness of the curd. The increase in temperature should not be so rapid that the exterior of the curd particles cooks more rapidly than the interior. Should this occur the final cheese is liable to contain excessive moisture which may give rise to many defects.

The acidity of the whey immediately after the curd is cut will be somewhat below that of the original milk, or about 0·10 to 0·12 per cent. This drop in the acidity is caused by the fact that the curd contains a portion of the salts of the milk which contribute to the acid test. When the acidity of the whey has increased to about 0·14 to 0·18 per cent the whey is drawn off. The condition of the curd particles, however, must be taken into account as well. After the whey is drawn off the curd is allowed to mat at a depth of about four inches or more, depending upon the quantity in the vat.

The curd is then cheddared. This involves holding it for some time, possibly two hours or longer, at slightly below the cooking temperature, although never below 90°F. The curd mass is frequently turned and replied. During this time the curd will not only mat more firmly together but will change physically from a tough corky mass to a rubbery, moist, plastic consistency. The free whey will largely although not completely drain off. The acidity of the whey that drains from the curd will continue to increase until it is between 0·40 to 0·60 per cent. Cheddaring is complete when the curd forms strings on a hot iron between one-half and one and one-half inches long or when it tears in shreads like the white meat of a roasted chicken's breast.

The curd is then milled or chopped into small pieces to aid in the distribution of salt, to allow for further draining of the whey and to make the curd easier to handle. It may or may not be washed but is salted, by the addition of two to two and one-half pounds of salt to 100 pounds of curd, and put into hoops or forms in which it is pressed. The hoops may be lined with pieces of fine muslin cloth, called cheese cloth. These surround

the completed print and protect it during handling thereafter. The use of cheese cloth bandages is objected to, however, by some cheese makers.

The cheese is pressed for 24 hours or so until the prints are well formed. They are then removed and placed in a cold storage room for a day or two until a crust or rind forms on their entire surface. It is necessary to turn the prints from time to time during this period in order to assure rind formation on all sides. This rind forms principally as a result of the evaporation of moisture from the surface of the cheese.

The prints are then paraffined, that is, coated with paraffin wax, by immersing them in the hot liquid wax. Wax prevents surface evaporation and offers considerable protection against the growth of moulds. The cheese is then placed in cold storage at 40° to 65°F. for curing. During curing the development of acid continues and other bacterial and chemical changes take place to bring about the formation of the desirable flavour and aroma and the desirable body and texture of the finished cheese. These changes are discussed briefly in Chapter VIII.

Soft Cheese

The making of soft cheese may be illustrated by the procedure used for Surati cheese (60), one of the very few cheeses indigenous to India which include also Dacca and Bandal cheese (22). Good quality milk is standardized to 6 per cent fat and heated to 172°F. for 20 seconds. After cooling to 95°F. a good culture of *Str. lactis* is added at the rate of one-half ounce of starter to 100 pounds of milk; following this, rennet is added at the rate of 6·7 millilitres to 100 pounds of milk, or sufficient to give a firm coagulum in about one hour. The curd is then dipped in layers into bamboo baskets which have been previously cleaned and sterilized. The cheese is salted by sprinkling a little salt on each layer of curd so that about two pounds of salt are used for each 100 pounds of milk. Drainage is accomplished by turning the cheese in the basket or inverting it from one basket to another every 30 minutes or so until all free whey is drained off. The cheese prints are then placed in the whey for 12 to 36 hours ripening. The length of the ripening period will depend upon the temperature of the whey and the final titratable acidity desired, which will be about 0·5 to 0·6 per cent.

This type of cheese will not keep more than a few days and must, therefore, be consumed almost immediately. The yield of Surati cheese is about 35 to 40 per cent of the milk used, depending upon the firmness of the curd at dipping, the completeness of drainage, the final salt content and the extent of ripening.

Both the Dacca and the Bandal types of cheese are made in a manner quite similar to that just outlined, except that they are smoked on the surface with wood smoke to increase their keeping quality. Dacca cheese is pressed for several days before smoking. Bandal cheese is made either from whole milk or cream. That made from cream has a softer body and a somewhat more mellow flavour than that made of whole milk.

Ice Cream

Ice cream is a frozen product of milk. It may be made of milk, or of milk and cream mixed in almost any proportions. The manufacture of commercial ice cream in some countries, particularly in the United States, is a very specialized branch of the dairy industry (92). Where laws exist defining the product and stating the minimum percentages of the constituents of milk or other materials permitted, the composition of the product is less variable than it is elsewhere.

It is not known how much ice cream is made in India, although it is estimated that 0·3 per cent of all milk produced is utilized for this purpose (18). This accounts for about 7,500 tons of milk annually. Ice cream is manufactured principally in Calcutta, Bombay, Madras, New Delhi and Bhopal.

Ice cream contains varying amounts of the different milk solids. These solids are usually grouped as fat and solids-not-fat or serum solids by the practical ice cream maker. In addition to these constituents, sugar is nearly always added as is also some flavouring and/or colouring extract or substance. Industrial ice cream commonly contains a substance, known as a stabilizer, which is added to give the product a certain firmness or quality of body not obtainable otherwise.

The milk solids-not-fat, or serum solids, used in ice cream may be added in the form of skim milk, whole milk, condensed or dried milk. If it is intended that the serum solids content of the ice cream mix should be greater than about 6·0 to 6·5 per cent, it is necessary to add these solids in a concentrated form,

such as condensed or dried milk. A common industrial mix in the United States contains 10 per cent serum solids.

The fat may be supplied by whole milk, cream, or possibly sweet, that is unsalted, butter. In most ice cream except some made in the home and a little which is sold by petty vendors who dispense directly from the freezer, the fat content of the ice cream mix is generally somewhat higher than it would be where only whole milk used. The fat content of ice cream sold in India probably varies from 4 to 14 per cent. This range is no doubt even wider for ice cream made in the home. Extra cream is commonly added to home made ice cream to increase its butter fat content, giving it a smoother, more creamy body and flavour.

Ice cream is commonly sweetened to taste by the addition of sugar, usually between 10 and 15 per cent. *Gur* may be used for sweetening and imparting its own characteristic flavour.

A great variety of flavours are used in ice cream. Probably the most common is vanilla. Chocolate or cocoa is common and burnt sugar is frequently used to give a carmel flavour. Any one or a variety of fruits will give ice cream its characteristic flavour. The addition of certain fruits influences the colour of the ice cream, although a harmless vegetable or synthetic colour may be added. Various nuts will supply their own pleasing flavours when added to an otherwise plain ice cream.

Stabilizers commonly used are gelatin, gum, agar agar, cereal flour or certain synthetic materials such as sodium alginate. The quality of the finished ice cream will depend to a certain extent upon the kind and amount of stabilizer used. The amount of stabilizer varies usually from one-fourth to one-half of one per cent of the weight of the mix. Of the natural materials employed, gelatin gives the best results. Some of the synthetic stabilizers have certain advantages over this material. Because gelatin is an animal product and would be objected to for that reason, its use may be limited in India. Vegetable products, such as gum or agar agar, may be used, but they are less satisfactory than gelatin. Sodium alginate is a satisfactory stabilizer, as compared to gelatin, and is not an animal product. The addition of stabilizers is not absolutely necessary in home made ice cream, although they are considered essential in the industrial type.

In making ice cream the materials from which it is to be

made must first be selected. Raw materials of good quality are essential. They must be fresh, have a good clean flavour and a low acidity. The composition of the materials to be used must then be determined. This may involve testing for butter fat and solids-not-fat in order to control the composition of the finished product. The next step is to calculate the amount of different materials to use to give the required quantity of mix of the desired composition. The proper quantities of the ingredients of the mix are then assembled and mixed together. To facilitate their complete and uniform mixing it is well to add them in the order of decreasing moisture content, that is, the whole milk to the skim, the cream to whole milk, and sugar to the liquid materials. Difficulties may be expected to arise if the liquid ingredients are added to the sugar; the sugar is likely to dissolve only with difficulty if this is done. The stabilizer must by all means be added only after it is mixed with the sugar while dry, otherwise it will be found to be practically impossible to get it completely into solution.

The mix is then pasteurized at 150°F., or even 155°F., for 30 minutes. A slightly higher temperature is used for ice cream mix than for whole milk to assure complete destruction not only of the pathogenic bacteria but also of any *B. coli* which may be present (92). Three purposes are accomplished in the pasteurization of the ice cream mix: 1. the ingredients are thoroughly dissolved ; 2. the disease producing and putrefactive bacteria are destroyed ; 3. the keeping quality of the ice cream is increased. Although milk is generally boiled by the consumer before it is used, this cannot be done to ice cream as it is a frozen product which would cease to exist as such if heat were applied to it. It is necessary, therefore, for public health reasons, to pasteurize all materials that are used in ice cream. This can best be done after they have been mixed together.

The commercial mix is then homogenized. One purpose of homogenization, as stated in Chapter VIII, is to prevent churning. The agitation to which the mix is exposed in the freezing process, particularly in the case of commercial ice cream, may readily cause churning. It is imperative that the mix be homogenized to prevent this as the presence of butter granules in this product greatly reduces its market value. Homogenizing pressures of 3500 pounds to the square inch are commonly used. Within certain limits this may vary, however, as desired by the

manufacturer. The mix is homogenized at the temperature of pasteurization.

Following homogenization the mix is cooled, usually by means of a surface cooler. The homogenizer, as well as the containers into which the mix is placed prior to freezing, may be a source of bacterial contamination subsequent to pasteurization. Cooling, as has been explained, retards bacterial growth; it does not destroy the organisms.

Holding the finished mix a short time before freezing is necessary to produce the best body and texture in the finished product if a stabilizer, particularly gelatin, has been used. During aging, hydration of the stabilizer and the milk proteins takes place, that is they imbibe quantities of water which thereby are not readily frozen; as a result, ice crystals in the finished product tend to be small. This gives the ice cream a smoother texture than would be possible without aging. Aging is facilitated by low temperatures. The mix should be aged, therefore, at as low a temperatue as possible without freezing.

Modern industrial freezers are of two types. The batch freezer handles a definite quantity or batch of mix at one time. This is removed before additional mix can be admitted. The continuous freezer receives mix and discharges ice cream continuously. The capacity of the latter is generally greater than the former. The hand freezer is a batch freezer. During the freezing operation two things are accomplished, namely, air is whipped into the body of the mix, giving an increase in volume which may be as great as 100 per cent or more of the volume of the original mix; secondly, the mix is partially, not completely, frozen. The increase in the volume of a mix during freezing is called overrun and is commonly expressed in percentage of the original volume of mix.

Coming from the freezer at a temperature of about 20 or 25°F. the partially frozen ice cream must be placed in a hardening room at a temperature not higher than 0°F. to complete the freezing. The butter fat temperature changes more slowly than that of the non-fat portion of the mix. When the ice cream is drawn from the freezer the water is largely frozen as tiny ice crystals while the fat contains considerable quantities of heat which, if conditions permit, may bring about melting of some of this ice. The lower the hardening room temperature the more rapidly that heat contained in the fat is removed and the less

likely it is to melt ice crystals which immediately surround the fat globules. Due to rapid freezing the ice crystals which form in the freezer are small. Were they to melt as a result of the heat being removed too slowly from the fat, they would subsequently reform rather slowly. This would cause the formation of large crystals which are undesirable because of the course icy texture of the ice cream that results. Sudden formation of ice crystals in the freezer followed by rapid hardening at low temperatures, therefore, produces the fine, smooth body and texture characteristic of good quality ice cream. Hardening of ice cream made in the hand freezer is brought about by packing it for a couple of hours or so with ice and salt after freezing is complete.

Ice cream may be held for several weeks before it is sold, provided the storage temperature is low enough. This temperature will depend upon the composition of the mix, particularly its added sugar content. A mix, however, of 12 to 15 per cent sugar, which is the degree of sweetness desired by most people, will soften above 0°F. The lower the temperature of storage the longer the storage period possible. Ice cream has been known to keep several months without appreciable deterioration. Under practical conditions it is not ordinarily kept longer than a month or so since chemical deterioration may occur. The expense involved in investing a large amount of capital in stocks of ice cream is sufficient reason for holding it as short a time as possible.

Home made ice cream is a different type from commercial or industrial ice cream. There are innumerable formulæ for home made ice cream, the simplest of which is a mixture of milk, cream and sugar, to give about 13 per cent of fat, sweetened to taste. This may be flavoured with vanilla or other flavouring materials and frozen in the ordinary hand freezer. The chemical composition of home made ice cream may differ very little from that of commercial ice cream, except for its serum solids content. Whereas in commercial ice cream additional serum solids are added in the form of condensed or dried milk, this is rarely done in home made ice cream. The result of inrceasing the fat content of and adding sugar to whole milk, as is done in making home made ice cream, is a lower milk solids-not-fat content than that of the whole milk originally used (see Appendix VIII). While the commercial freezer is operated by the

17

use of mechanical refrigeration, the hand freezer is operated by the use of ice to which salt is added. Added salt does not appreciably lower the temperature of the ice, but does reduce the temperature at which its latent heat of fusion is absorbed, that is, the temperature at which it melts. The tremendous amount of heat required by the ice before it will melt is consequently removed from the mixture or the surrounding atmosphere not at 32°F., which would be true without added salt, but at a somewhat lower temperature. The amount of added salt in ratio to the quantity of ice will determine the temperature at which the melting of the ice will occur. Such a temperature may be as low as -6·16°F. in a mixture of 1 part of salt to 3·65 parts of ice (92). In practice, however, one part of salt is used for six parts of ice.

Kulafi

A frozen product, known as *kulafi*, usually containing some milk, is common to certain parts of India. *Kulafi* is made by filling a small tin container, about one inch in diameter and two to three inches long, with the proper mixture. The container is then covered and immersed in a salt-ice brine where freezing occurs. The mixture is usually sweetened and coloured and flavoured with fruit juices or other materials. Milk is usually present in small proportions, although the water content of the mixture is very high. *Kulafi* is frozen without agitation, consequently it is very coarse and icy. It is similar in some respect to a product made by colouring and flavouring of ice chips by the addition of highly coloured fruit juices.

Evaporated and Condensed Milk

Small quantities of evaporated and condensed milk are made in India. Two methods of preparation are possible, namely, the vacuum pan and the open pan methods. Evaporated milk is prepared by removing a considerable portion of the water from milk by evaporation (45). If sugar is added to give a sweetened product it is known as condensed milk (44). The final volume is about one-third that of the original milk. Evaporation may be carried out under a vacuum, however, to take advantage of the fact that rapid evaporation of the water takes place at much lower temperatures as the pressure is reduced. For example, milk boils vigorously at about 145°F. under a vacuum of 23

inches. The exposure of milk and its respective constituents to low temperatures causes only very minor changes as compared to temperatures of 212°F. or higher. The quality of the product produced by the vacuum pan method is much better than is possible by the open pan method.

In the manufacture of evaporated milk the milk is first forewarmed, that is, heated to between 145° and 230°F., in order to increase its heat stability and thereby reduce its tendency to thicken during manufacture and storage. The bacterial count of the milk is greatly reduced by forewarming. If condensed milk is to be made, the necessary sugar is added to the milk while in the forewarmer. The milk is then drawn into the vacuum pan where it is condensed until the required degree of concentration is attained. It is then removed, cooled and packaged. If the product has been sweetened it should be cooled as fast as possible to assure a fine texture, for the more rapidly sugar crystals form the finer they will be. Evaporated milk is sterilized after it is sealed in the tins in which it is to be marketed. This assures its keeping quality. The high solids and high sugar content of condensed milk are usually sufficient to assure the keeping quality of this product for a considerable period of time, provided it is not highly contaminated. Certain yeasts and moulds, for example, may grow on the surface of or in condensed milk even after it is tinned. When this occurs, a poor quality product will result.

Powdered or Dried Milk

Milk may be dried by the roll process or the spray process (45). In the roll, or film, process milk is partially condensed and then passed over the surface of a heated roller. The temperature of the roller is such that the moisture is evaporated from the film of milk adhering to it, leaving only a thin layer of milk solids which is scraped off and ground. The thickness of the roller shell, variations in the density of the metal of which it is made, variations in the thickness of the milk film and other possible factors combine to give scorching of the milk solids in certain areas on the roller. For this reason, the quality of powdered milk made by this method is not as good as that prepared by the spray method.

In the spray process, partially condensed milk is atomised

as it is directed into a strong blast of hot dry air. Each minute droplet of milk is carried in this air until its moisture content is so reduced that only a particle of dried milk remains. These particles settle out or are filtered out as the air is discharged from the drying chamber. The solubility of spray processed powder is usually greater than that made by the roll process mainly because the rate of evaporation as well as the maximum temperature to which the milk is exposed is more uniform. This powder is commonly used for human consumption or in the preparation of special foods for infants.

CHAPTER XII

PRODUCTION RECORDS

The value of production records depends first of all upon their accuracy. Inaccurate entires, through negligence or other causes, help to complete such records, but they do not represent the performance of the cow, the very thing such records are intended to do.

The recording of the production of milk and butter fat of individual cows is considered necessary in countries where appreciable progress has been made in the development of high quality milk producing animals. Milk recording is a common practice wherever dairying has made its greatest progress. All enterprises must be carefully considered in terms of their utilizaation of goods and services per unit of product. Of the goods and services employed in the production of milk, feed, depreciation and human labour are the most expensive per unit of milk or per unit of fat (49).

A common criterion of efficiency is the cost of producing a unit of milk in terms of currency units, or rupees. This basis is not always reliable for prices of feed and labour may change through no fault of the cow. Should all prices exactly double, then the cost of production would double, the income would double and the profits or losses in terms of rupees would double. Such a condition may occur with absolutely no change whatsoever in the efficiency with which a cow converts feed and human labour into milk. Costs of milk production in terms of currency units, therefore, cannot represent the efficiency of milk production so well as costs in terms of units of feed and man power. More recently the utility of dairy cattle is being measured in terms of the efficiency with which they convert food energy in the form of fodder and concentrate feeds into food energy in the form of milk. In this case the calorific value of the milk produced is expressed in percentage of the calorific value of the feed con-

sumed. Such a measure is possible only where the calorific value of all feed materials and of milk of varying composition is known.

Quantity of Milk and Butter Fat Test Both Required

In a market for fluid milk, a greater price is generally paid for milk in terms of units of volume or weight than units of food value. That is, the price is fixed per pound, seer or quart. The butter fat content of the milk in such a market may vary as much as from 3·5 to 8·0 per cent, although more commonly from 4·0 to 6·0 per cent. The price obtained in the ghee or butter markets, on the other hand, varies roughly with the food energy or calorific value of the milk, since such a price varies with the butter fat content. Of the constituents of milk, butter fat is the most important contributor to its calorific value, because of both the greater calorific value per unit weight of fat and the fact that the proportion of fat present in the milk varies more than that of any other constituent. In the production of milk for private use its food value should be of equal, probably greater, importance than its volume. For making butter or ghee, for domestic use or for a market based on the butter fat percentage of the milk, the measure of efficiency of a milking animal is primarily her production of pounds of butter fat. The percentage of butter fat indicates how much of this constituent there is present in a unit of milk; the weight of milk makes it possible to determine the total quantity of fat produced. These two values, therefore, are needed to measure an animal's producing efficiency in terms of a market for either fluid milk or for butter fat, a market for volume or food value.

Other reasons why the quantity of milk and its butter fat content are required to show the producing efficiency of a milking animal were stated in Chapter II. It is now thought that both the quantity of milk and the quality of the milk are independently inherited characteristics. The environment, however, may greatly limit the expression of these characters. This is partly explained in Chapter IV in the discussion on the factors causing variations in the chemical composition of milk. Inadequate feeding or care will reduce the yield of milk and have certain effects on its composition, whereas adequate feed and care permits the animal, provided her health is normal, to pro-

duce all the milk and fat she is inherently capable of producing. The producing ability of a cow may be expressed in terms of the quantity of milk she produces; the percentage of butter fat it contains; or, preferably, the pounds of butter fat produced, which is the product of the pounds of milk and the per cent of butter fat. Careful production records which show the weight of milk and its butter fat content, therefore, are of value in showing the utility of a dairy cow as a producer of milk for any type of market, in showing which cows possess the greatest producing potentiality or inherent capacity to produce and in showing whether the environment provides adequate feed, water and care. Such records must be supplemented by individual feed and breeding records.

Reasons for Maintaining Production Records

An Australian writer (83) gives eight reasons for keeping milk records. They are:—

1. Milking records constitute a guide for the feeding of each cow according to the quantity of milk she produces. Records stimulate better feeding and breeding. The dairy farmer who keeps records usually feeds a balanced ration and becomes interested in winter feeding, and so maintains his milk supply throughout the year.

2. The weighing of the feed and milk keeps the dairyman in close touch with the daily condition of each cow; ill-health is thus readily observed.

3. Milking records form the only basis on which a herd can be improved.

4. No careful dairy farmer will buy a bull for use in his herd whose dam has not an authentic record, showing creditable milk and butter fat production.

5. Records alone will sell cows when no other quality will. Grade cows with records can be sold for from 25 to 50 per cent more than those for which there are no milking records.

6. A system of records is the first step in building up a herd. Unprofitable cows are the most expensive; their heifer calves are usually low producers and should not be kept for the milking herd.

7. Records also stimulate better milking. Milk scales serve as a check on the milker and induce him to milk more thoroughly than when the milk is not weighed. A knowledge of what each individual cow is doing develops personal pride and interest in the herd.

8. Finally, records make dairying a business proposition and, in various incidental ways, mean more money to any one who milks cows for a living. A maxim which should be prominently displayed in every milk shed is—"The cow, not the herd, is the unit of profit."

Another reason which may be added to these is that milk records are indispensable in any systematic programme of selective breeding.

Demands for Food Energy in the Dairy Cow

A variety of demands is made of the milk producing animal during her lifetime, so far as her utilization of food energy is concerned. During prenatal life, the requirements of the foetal body are met by the mother, but from birth onwards, except for milk provided by the mother during the nursing period, the individual must obtain its own energy from other sources.

The basic demand for food energy in any living being is for maintenance of the body. The amount required for this purpose will depend upon the age, body weight, size and genetic ability of the animal to utilize and adapt itself to the food supply available. The processes of blood circulation, respiration and digestion all require a certain amount of energy which must be available at all times, either directly from the food which is ingested or from supplies stored in the body, to maintain life. A certain amount of energy is required for moving about to get food and water. Domesticated animals utilize less energy as a rule for this purpose than wild animals. Energy is continuously being utilized for combating infections and maintaining health. These requirements must be met before it is possible for the animal to increase its body weight.

The food requirements for body growth are large during the first few years of the lifetime of the dairy animal. This demand continues from birth to physical maturity which may occur at between four and six years of age. Where suitable feed is provided in adequate quantities, physical maturity will occur at about four years or so of age in the zebu, or about five years in the

buffalo; under village conditions this may be delayed to as late as the 6th and 7th years respectively. Sexual or physiological maturity may occur as early as 15 to 18 months of age in the zebu with good feed and care, although as late as 36 months in the village animals.

Mature dairy animals are required to maintain their bodies, reproduce and produce milk. Feeding must be adequate to supply the needs for body maintenance, with additional quantities for reproduction and milk production. Such animals, except for the bullocks or, occasionally, the bulls, are rarely required to work.

Small quantities of heat energy are utilized by the dairy animal during oestrus or sexual excitement. Still larger quantities, however, are required during pregnancy for the development of the foetus. The number of times oestrus recurs before conception is brought about and the number of pregnancies determines the total energy required during the lifetime of the animal for these purposes. Undoubtedly, there are considerable differences in the inherent capacity of different animals to utilize energy for these purposes. This has not yet been measured, however, except indirectly by noting the number of services per conception, the length of the calving interval, the length of the dry period, and the number of pregnancies during the lifetime. These are then taken into account in assessing the utility of the animal as a milk or dairy animal, considering the facts that, apart from the production of milk in quantities as large as possible, the reproduction of the herd is essential and that each parturition initiates a new lactation.

The secretion of milk is a physiological function of female mammalia which is very closely connected with reproduction. The natural purpose of such a function is the nourishment of the young. Fundamentally, milk secretion occurs only after parturition. It tends to continue at least until the young has developed sufficiently to tolerate other food materials. The duration of the lactation or milk producing period varies from one species of mammals to another. Reproduction in dairy animals, therefore, is needed in order that milk secretion might be initiated.

Heat Energy Conversion as a Measure of Utility

Where it is possible to do so it is worthwhile to assess the pro-

ducing capacity of a dairy animal in terms of the efficiency with which food energy in the form of fodder and grain is converted into food energy in the form of milk. This has been attempted by Gaines (36). Gross efficiency, as defined and used by Gaines, is the heat energy value of milk, corrected to 4 per cent butter fat, expressed in percentage of the heat energy value of the feed ingested during the lactation. What might be called the over-all gross efficiency (50) would be still more inclusive. This involves the expression of the heat energy value of the milk, corrected to a 4 per cent basis, in percentage of the heat energy value of the feed ingested during a calving interval ; this includes the feed consumed during the dry period which must be paid for by the production of the animal before she becomes a profitable animal.

It might be better, in line with the suggestions just made, to employ a term such as "lifetime over-all gross efficiency" in which the heat energy value of the milk produced during the lifetime of the cow, corrected to a 4 per cent or other standard basis, is expressed in percentage of the heat energy value of all milk, skim milk, grass, fodder and grain feeds ingested during her lifetime. Such a method of expressing producing efficiency would include all the various factors now involved in the production of milk on the part of the dairy animal. It is not possible to employ this method, however, until the heat energy values of each of our common fodder and grain feeds is known. Formulæ by which to convert milk of various fat percentages into standard milk, possibly 5 per cent for India, would greatly facilitate the use of this method of assessing producing ability in dairy animals.

Production and Supplementary Records

Breeding records must include, besides the pedigree of the cow, or bull, involved, her age at first service, the date of each service thereafter, the date of each calving, the bull to which she was bred and the sex and number or name of each calf. Such records must be maintained throughout the lifetime of the cow to be complete.

Feeding records should include the date of birth; body weight taken monthly during the growing period and at intervals of three months or so thereafter; and the amounts of whole

milk, skim milk, fodder and concentrate feeds, including kinds, given daily throughout the life of the animal. It would be worthwhile if such records were to include also the monthly, lactation and calving interval totals of feeds to supplement production figures for these periods.

Production records should include the date of each calving; the weight of milk produced at each milking throughout each lactation with daily, monthly and lactation totals; the butter fat percentage of twenty-four-hour samples taken at least once a month; the pounds of fat produced during the period represented by each butter fat test and during each lactation; and the date of drying. From the first and the last of the items listed it will be possible to determine the length of each lactation, of each dry period and of each calving interval. Production records should be maintained throughout the lifetime of the animal, as was suggested for breeding records.

The production records might well include the daily milking average for the lactation and for the days in milk during the lifetime. They might also include the over-all daily milking average for each lactation except the first, based on the days in milk plus the days dry preceding the lactation in question, and the total yield of milk during the lactation. Another figure which should prove extremely useful, although as yet never used, would be the "over-all lifetime daily average" which would be derived from the lifetime in days and the lifetime production of milk. Each of these averages based on pounds of butter fat rather than pounds of milk might, as a matter of fact, prove more useful in indicating the producing utility of an animal, since pounds of fat is a product of the two characteristics, pounds of milk and fat percentage, which are measures of productivity and which are separately inherited. An accurate assessment of breeding, production and feeding records is a valuable index to the inherent ability of an animal to produce milk. Such records will indicate the producing utility of an animal and can be relied upon to distinguish the low producers from the high producers. It is essential, however, to take into account the age at first calving and the length of the dry periods thereafter, together with maximum daily production, persistency of production and total production during each lactation. An animal which is dry half her lifetime, for example, is certainly less likely to produce

as much milk as one which is dry only one-third of her lifetime. Longevity is also to be considered, for a milking animal which first freshens at about 4 years of age and lives for only three years thereafter is hardly likely to prove as economic as one which first calves at 2½ years of age and lives for another ten years. Calving intervals of 18 months in the first instance as compared to 14 months in the latter only aggravate the difference in the economy of production of milk and fat by the two animals.

Milk Recording in India

Milk recording has not been undertaken extensively in India. Less than 0·03 per cent of our cattle are being recorded at present (18). Those on which records are being kept are some of the best that we possess, consequently such records do not indicate the average milk production of our cattle. The extensive use of milk recording in Denmark prior to the war was sufficient to make it possible for the average production of milk and butter fat of Danish cattle to be obtained from those records. Probably nowhere else has recording been practised so extensively and probably nowhere else has improvement been so great in such a short period of time as in that country. Between 1899 and 1938 the average annual production of Danish cows increased 69 per cent, that is, from 4322 pounds to 7260 pounds, and the average butter fat percentage increased by over 0·4 per cent (79). This progress was possible only because of the milk recording carried out in that country during the period involved. It was a Danish lady, Mrs. Frederick Hansen, who first conceived of a herd improvement or cow testing association, called a Control Society in Denmark; and a Danish man, Emil Konradi, who, in 1895, became the world's first cowtester (79). The recording of the quantity of milk produced by individual cows dates back to before 900 A.D. in Wales when the milk was measured by a Venedotian measure, holding about one gallon (69).

The yield of milk may vary several times as much as the butter fat content of that milk. For this reason it is more important that only the quantity of milk be recorded than only the butter fat content of that milk. Records are incomplete, however, unless they include both the quantity of milk and its

butter fat content. From these the quantity of fat may be calculated.

Milk recording is confined largely to Government and other organized herds in India. Records in these cases commonly, though not always, include the fat percentage as well as the quantity of the milk. Between 1940 and 1945 some recording has been undertaken on village animals in various places, with the help of the Imperial Council of Agricultural Research. Records obtained on these animals, however, include only the quantity of milk, although it is proposed that the butter fat records be obtained as soon as possible. Both records are necessary.

The common practice or raising the calf by the natural nursing method has been discussed elsewhere. Where this method is followed, milk records show only the amount of hand-drawn milk and possibly the butter fat percentage of such milk. The reliability of such records is variable. The calf may be allowed to nurse before hand milking or afterwards, or it may be allowed to suck one or two quarters of the udder. In the first case, the milk consumed by the calf is the fore milk which contains a very low fat percentage; if allowed to nurse after hand milking, the milk involved is the strippings which have a rather high fat content. So far as the effect of the natural nursing method of calf raising on the butter fat record is concerned, it is probably better to allow all the milk of one or two quarters to the calf, so that whatever is hand-drawn is more representative of the total production. In neither case, however, can the records be relied upon as authentic with regard to the fat production of the cow, for just what the relationship is between the quantity and quality of milk from one quarter as compared to another or from two quarters on one side of the udder as compared to the two on the other is not accurately known. Were this known, the reliability of weighing the hand-drawn milk from two quarters and multiplying by two to get the total milk would also be known. Testing the milk produced by two quarters and assuming that the test obtained is representative of the milk from the other two quarters would then be a practice of known reliability; at present it is not.

Other methods are used, but, like those just discussed, their reliability is unknown. The calf may be weighed both before and after nursing to determine the change in weight which is

assumed to be the amount of milk it consumed. The calf may be withheld from the cow for one full day in seven when the milk is completely hand-drawn, weighed and possibly tested. The best method obviously involves the weaning of the calf, the complete regular hand milking of the cow and the regular weighing and testing of the milk so obtained.

The conventional measure of producing capacity in zebus or buffaloes used by our cattle dealers and dairymen is the maximum daily yield of milk, usually expressed in seers. Most dealers fix their prices for milk cattle on this basis, the rate varying with the market and general price level. Prior to the war a common price for good milk stock was between Rs. 10/- and Rs. 15/- a seer. A cow capable of giving 10 seers of milk a day, for example, cost thereby between Rs. 100/- and Rs. 150/-. The animal was usually delivered shortly after parturition when she was producing her largest amount of milk. The exact relationship between the maximum daily yield and the total lactation yield has not been determined. Casual observation, however, will show a ratio of somewhere between 1: 180 to 1: 200 between the two. That is, if the maximum daily yield is 15 pounds, the lactation total can usually be expected to be between 2700 and 3000 pounds. This relationship is not rigid, but it will give some idea of the lactation total which may be expected if the maximum daily yield is known, or vice versa.

The Lactation Curve

The lactation curve shows the daily production of milk plotted against time. Two characteristics of this curve deserve special attention. These are the maximum point reached and the rate at which the curve drops off thereafter. The curves given on page 261 show the significance of these points.

The areas under each curve can be taken to indicate in a very rough manner the total production for each lactation represented. Neither of these curves actually indicates the production of any particular animal, except possibly as a result of chance. Nor should the curves be taken to indicate the exact geometric nature of typical lactation curves. They do, however, in a general way, show the shape of such curves. The curves in figure A compare the effect on the total lactation production of a high

and a low maximum daily yield. With roughly the same persistency of lactation in curve BMD as in BM'D, the lower maximum point, or maximum daily production, in the latter results in a considerable decrease in the total milk produced for the lactation. In figure B the two curves show in a general way what effect persistency of lactation, even with the same maximum daily yield, has upon the total lactation production. Whereas curves BMD and BMD′ reach the same maximum point at the same time after parturition, the total production in the lactation represented by BMD is fully twice that of BMD′ as a result of the more rapid decline and earlier cessation of the production of the latter. As the pounds of butter fat represents the product of two separate and very important factors in

Fig. A

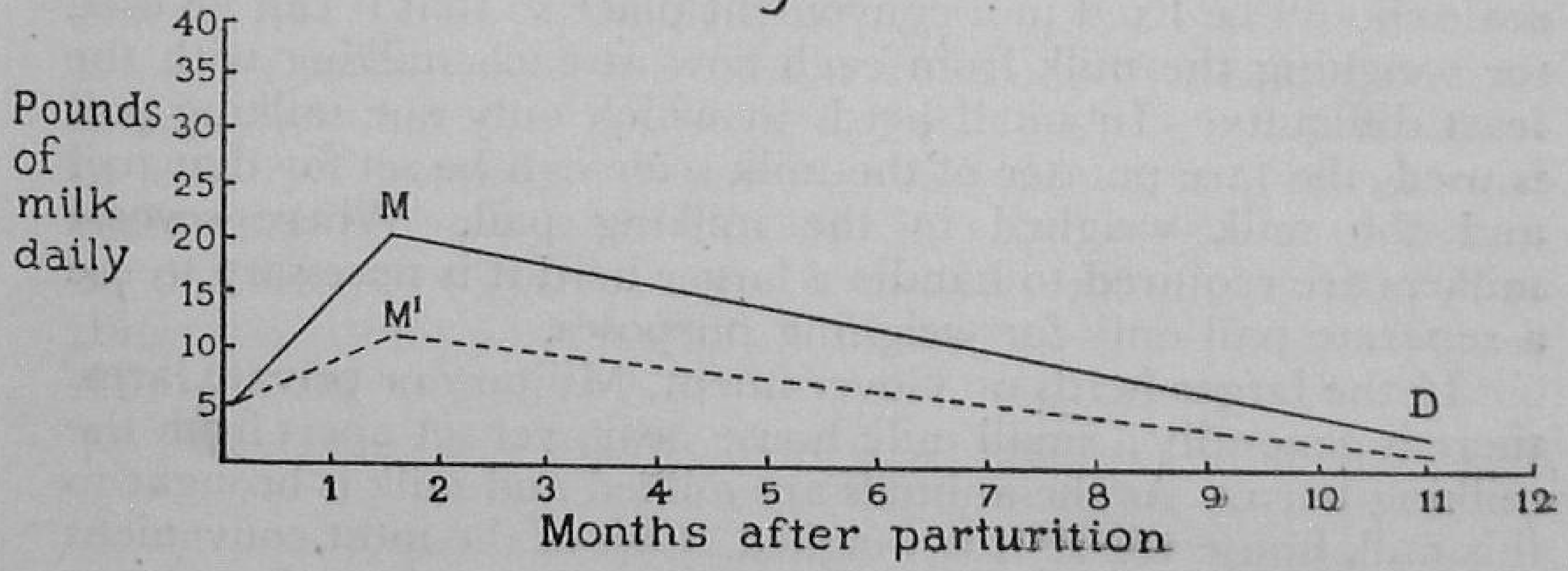
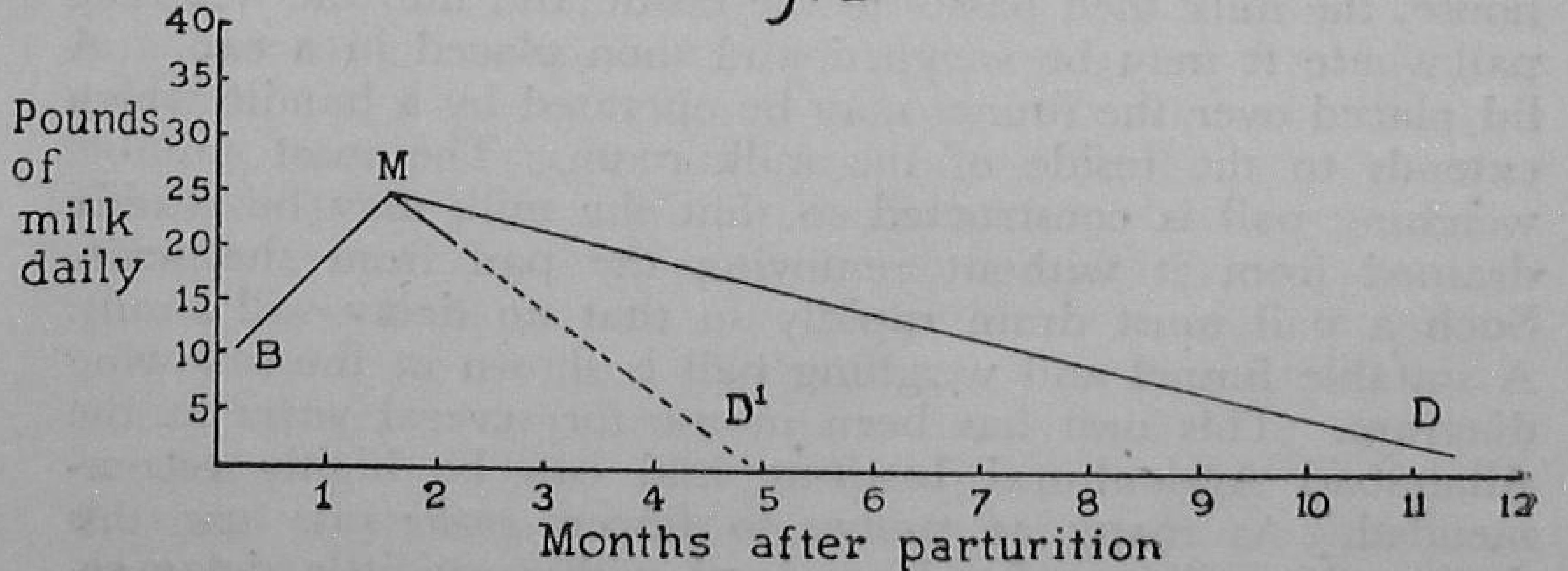


Fig. B



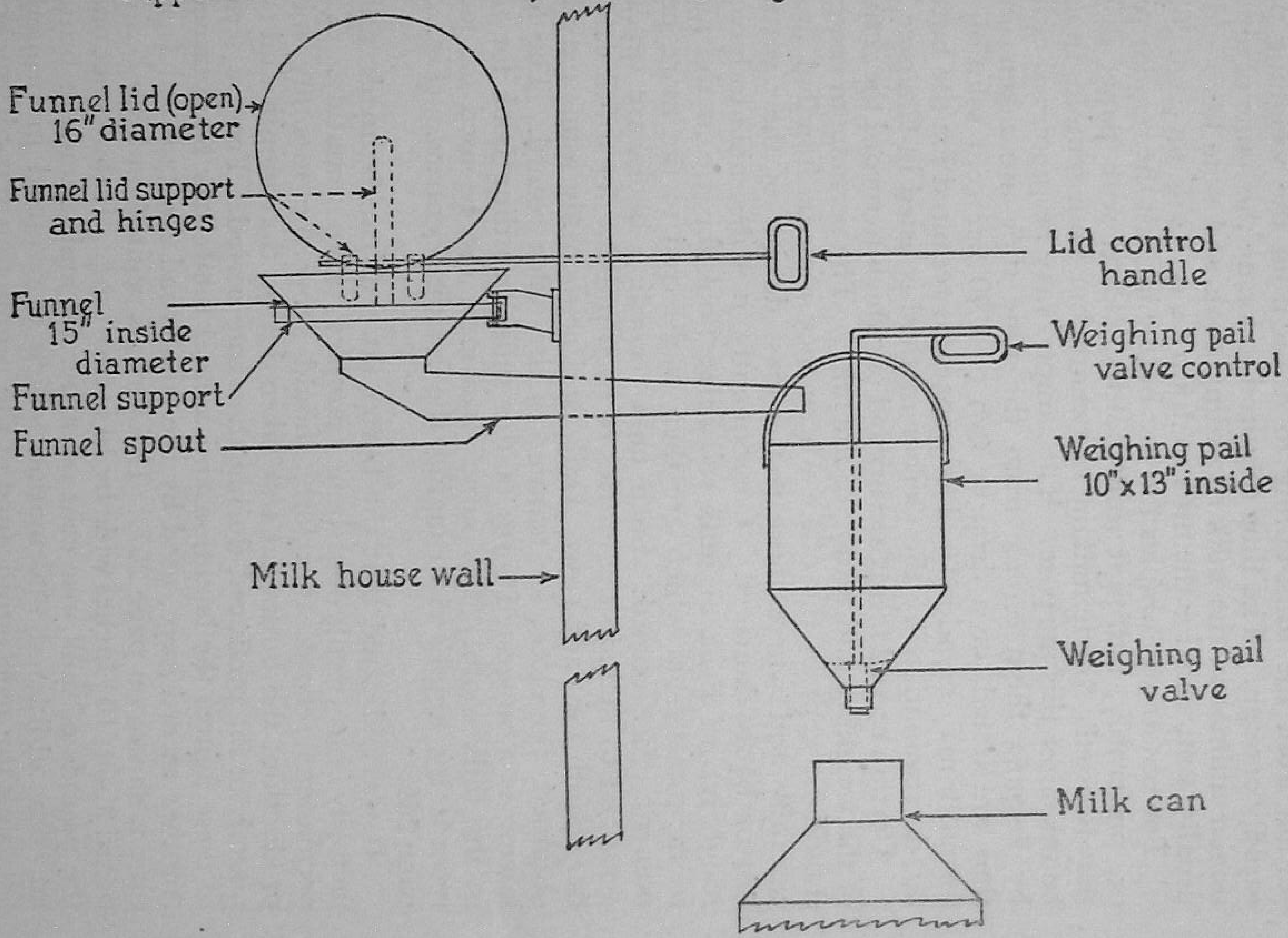
determining the producing utility of a dairy cow, so the total lactation production represents the product of two very important factors—the maximum daily yield and the persistency of lactation—in determining the milk production of a dairy cow. Obviously, the maximum daily yield is of questionable value as an indication of producing capacity, if considered apart from the date of drying, although it is commonly used, at least in northern India. The total production of the lactation is of greatest importance, particularly if considered in connection with the date of freshening, the date of drying and the maximum daily yield.

Equipment Required

The apparatus and supplies required for milk recording are rather simple. A good spring scale, preferably calibrated to 0·1 of a pound, is sufficient for determining the yield of milk. This scale should be fixed in a convenient place so that it can be used for weighing the milk from each cow at each milking with the least difficulty. In small herds in which only one milking pail is used, the tare pointer of the milk scale can be set for that pail and the milk weighed in the milking pail. Where several milkers are required to handle a larger herd it is necessary to use a separate pail only for weighing purposes.

In the larger herds on Government, Military or private farms there is generally a small milk house near, yet set apart from the milking barn. As the animals are milked and milk is brought to this milk house where it is weighed. One of the most convenient methods of receiving the milk here is by means of a large funnel, the spout of which is at right angles to the mouth. The milk is received in the mouth of the funnel outside the milk house, the milk then passes to the inside and into the weighing pail where it may be weighed and then placed in a can. A lid placed over the funnel may be operated by a handle which extends to the inside of the milk room. The most suitable weighing pail is constructed so that the milk may be readily drained from it without removing the pail from the scale. Such a pail must drain rapidly so that no delay will result. A suitable funnel and weighing pail is shown in the following diagram. This unit has been in use for several years at the Allahabad Agricultural Institute and can be highly recommended. As many as twelve to fifteen *gwále* may use this during the milking of a large herd with very little delay re-

Apparatus for receiving and Weighing milk at the milk house



sulting from the milk failing to drain from the weighing pail rapidly enough. The time required to locate the name of a particular animal in the milk recording book and note her yield is usually sufficient for the milk to drain away. (Fig. on page 263.)

For obtaining samples for the butter fat test the regular pint or, preferably, half-pint milk bottles, closed with paper disks, may be used. Single milking or twenty-four-hour samples should be taken for this purpose. The samples may be preserved either by keeping them on ice from the time they are taken until they are tested, or a drop or two of a 40 per cent solution of formalin may be added. The apparatus required for the butter fat determination by the Gerber method is listed in Chapter V.

Certain record forms are needed on which to record the results of the weighing and testing of the milk. The permanent records should be kept in the office where they may be handled more carefully and where there is the least danger of their getting lost or badly damaged. Consequently, it is desirable to have a rough record book or milk recording book for use in the milk room, totals from which are then transferred to the more permanent office record. Such milk recording books are usually arranged to include the entries of each milking for a full calendar month for each cow. Daily and/or monthly totals may be obtained, therefore, for transfer to the office record. The following is a suggested form of this milk recording book for use in the milk room. The same form may also be used for feed records by simply rearranging the heading entries. (Fig. on page 265.)

It was indicated that the butter fat tests can be made satisfactorily on twenty-four-hour samples taken monthly. The permanent record, therefore, should show the monthly milk production, the butter fat test taken during that month and the pounds of fat produced during the same period. From a series of these figures the lactation and annual totals may be obtained. Another record form, used by the Allahabad Agricultural Institute, is shown on page 267. This form is printed on heavy cardboard about 10½ inches wide by 14 inches long. It shows not only the pounds of milk, per cent of butter fat and pounds of butter fat, but additional information which is required in properly assessing the true significance of the production records, such as the breeding, service and calving records, the drying date, the length of the lactation and length of the dry period in days.

RECO

		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th

FOR

16th	17th	18th	19th	20th	21st	22nd	23rd	24th	25th	26th	27th	28th	29th	30th	31st			

HISTORY SHEET

Cow.................... .... No.......... Age at first calving.................. Age died/sold..............

Bull & Name Breed and No.	Number of Services Date Conceived	Date Born Weight	Condition Disposal	No. Sex		Jan.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual yield Lactation Yield	Avor % Fat	Days in Milk	Date Dried on Days Dry
					Lb. Milk										
					% Fat										
					Lb. Fat										
					Lb. Milk										
					% Fat										
					Lb. Fat										
					Lb. Milk										
					% Fat										
					Lb. Fat										
					Lb. Milk										
					% Fat										
					Lb. Fat										
					Lb. Milk										
					% Fat										
					Lb. Fat										
					Lb. Milk										
					% Fat										
					Lb. Fat										
					Lb. Milk										
					% Fat										
					Lb. Fat										

The opposite side of the card has spaces for the pedigree of the animal covering three previous generations, with production records of the three nearest female ancestors; for indicating general body markings; for a veterinary record; for recording body measurements; for general observations; and finally a cross-ruled area in which to indicate body weight and growth curves. A record of this type is permanent and shows the lifetime history of the animal at a glance.

A similar card is used for bulls. One side of this card is identical to that used for the cow, that is, the side not shown but described in the paragraph immediately above. The production, service and calving record for the cow, shown above, is replaced by space for the breeding record showing the dam, her yields, the services required per conception, the date of birth and weight of the calf, the yields of female progeny and a comparison between them and their dams. This form is shown on page 269.

Outstanding Production Records

The world's record production of milk in 365 days was set by Carnation Ormsby Madcap Fayne, a 9-year-old Holstein-Friesian cow in the United States. She gave 41,943·4 pounds of milk during a period of 365 days ending in May, 1943. Her maximum daily yield was 146·5 pounds, reached during a period of 20 successive days during which she averaged 140 pounds daily (112). This excelled the previous record of 41,644·5 pounds of milk set by an unpedigreed Shorthorn cow, called Cherry, in England (6).

The average production of farm cows prior to the war in England was between 5000 and 5500 pounds while that of milk-recorded herds was 7000 to 7500 pounds; the figures are somewhat lower now (24). The annual production in the United States in 1942 was 4739 pounds of milk and 187 pounds of fat per cow (104). The figures for Denmark, an average of 7260 pounds of milk and 274 pounds of fat annually for all cows in 1938, (79) were mentioned earlier.

In comparison with these figures, the average annual production of all zebu cows in India is estimated to be 486·7 pounds of hand-drawn milk plus an estimated 300 pounds consumed by the calf, or 786·7 pounds; the figures for the buffalo cows are 1229·2 plus 300, or 1529·2 pounds (18). Considering the

BREEDING RECORD

Bull.................................*No.*.................. *Age* *died / sold*...........................

Name and Breed of Dam	No.	Yields of Dams			No. of Services	Birth Date and Weight	Name of Progeny	No. and Sex	Yields of Daughters			Daughter–Dam Difference
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												

fact, however, that the zebu is largely used for draft purposes, the production of milk for zebu cows does not compare so unfavourably with that of the buffaloes as these figures indicate. It is unknown, unfortunately, how much milk is produced annually by those zebu cows kept only for milking purposes. Some information to show the production of milk by both the zebu and the buffalo cows is available through the publications of the Imperial Council of Agricultural Research. The first of these deals with the production and consumption of milk in seven breeding tracts, that is, to quote the report. 'The areas are...... true samples of important....cattle breeding tracts where working bullocks are also produced' (53). The second is a series of reports entitled Milk Records of Cattle in Approved Dairy Farms in India (52 and 54).

The Village Inquiry (53) showed that the production of milk was 943 pounds during 8·8 months of a calving interval of 18·2 months for zebus and 2160 pounds during 10·0 months of a calving interval of 18·0 months for the buffaloes. The average pounds of milk per lactation for the individual tracts are as follows :

Tract	Zebu	Buffalo
Montgomery	1343·8	2470·0
Hariana	986·0	2575·4
Kosi (United Provinces) ..	865·0	1768·4
Bihar	651·3	1254·7
Central Provinces ..	411·3	1513·1
Kankrej	919·8	1890·2
Ongole	1236·4	1903·4

Records of the production of cattle in approved dairy farms are stated to be 'not officially tested milk records in the sense in which they are understood in other countries. They are simply records which in the opinion of the Imperial Council of Agricultural Research are carefully and accurately kept, and are meant only as a start in the direction of the official publication of milk-yields.' Records received by the Imperial Council of Agricultural Research during 1936-37 and 1937-38 have been published (52 and 54). The publication of the records of later years awaits the availability of paper and other materials and services after the war. Those published so far, however, are summarised on page 271. All figures are those of farm-bred animals, except as indicated.

Breed	Lactation yield in pounds*		Length of lactation in days		Length of dry period in days	
Zebu	1936-37	1937-38	1936-37	1937-38	1936-37	1937-38
Amritmahal ..	3284(12)**	2103(2)**	514**	357**	231**	132**
Deoni ..	2673(2)	—	263	—	121	—
Gir ..	2753(5)**	3721(11)	195**	333	197**	111
Hariana ..	3459(101)	3426(81)	302	308	115	150
Kankrej ..	3232(54)	3159(54)	305	303	184	178
Krishna Valley ..	2595(11)**	—	292**	—	181**	—
Malvi ..	2469(1)	—	285	—	175	—
Ongole ..	2938(10)	3164(9)	316	303	141	129
Red Sindhi	3604(85)	3934(62)	296	325	139	123
Sahiwal ..	4269(17)	5085(224)	306	308	128	193
Tharparkar	4056(89)	4056(109)	281	267	118	162
Buffalo						
Murrah ..	4113(97)	4048(705)	299	281	128	138
Nili ..	5212(2)**	5959(2)**	367**	361**	214**	132**
Surti ..	4359(4)	—	479	—	150	—

*Figures in brackets show the number of records involved.
**Figures for purchased animals.

The following table shows the highest lactations reported for each bred during the two years for which records have been published. The figures for 1937-38 are based on the daily over-all yield rather than total lactation yield, as is true of those for 1936-37.

Breed	Lactation yield in pounds		Length of lactation in days		Length of dry period in days	
Zebu	1936-37	1937-38	1936-37	1937-38	1936-37	1937-38
Amritmahal ..	14091*	—	427*	—	237*	—
Deoni ..	2807	—	247	—	136	—
Gir ..	3672*	5652	344*	463	220*	60
Hariana ..	6705	6680	354	292	97	139
Kankrej ..	6154	6073	344	358	456	158
Krishna Valley ..	3487*	—	356*	—	177*	—
Malvi ..	2469	—	285	—	175	—
Ongole ..	4842	5237	266	365	160	46
Red Sindhi	6541	9283	385	351	145	89
Sahiwal ..	10153	13692	406	551	94	69
Tharparkar	7119	9655	304	305	82	138
Cross-bred ..	17545	19682	425	426	85	419
Buffalo						
Murrah ..	8741	8198	443	418	257	198
Nili ..	6362*	—	392*	—	188*	—
Surti ..	7089	—	726	—	410	—

*Figures for purchased animals.

The Imperial Council of Agricultural Research financed milk recording in the villages of certain areas for several years in the hope that information showing the production of animals under village conditions might be made available and that milk recording on the part of the village cattle owners might be encouraged. Some results of this work have been published in INDIAN FARMING beginning in the issue for September 1942. At the same time two special sections of that publication were started which are devoted to records of zebus or buffaloes which exceed 10,000 pounds of milk in one lactation and to records of the buffaloes which exceed 7,500 pounds. Each issue of this publication since that time contains a report on the village milk recording schemes concerned.

One of the best records so far reported for a village cow was that of a Murrah buffalo in the Rohtak district of the Punjab. This cow, owned by Naki, son of Hardiwari, freshened on the 20th of December, 1942 and produced a total of 10,100 pounds of milk in a lactation of 390 days; her maximum daily yield during this lactation was 42 pounds (67).

Maximum yields reported for other breeds under the village milk recording scheme of the Imperial Council of Agricultural Research are as follows.

Breed Zebu	Lactation yield in pounds	Length of lactation in days	Date of calving	Maximum daily yield in pounds
Hariana (66) ..	5858	314	15-9-41	—
Kankrej (68) ..	3006	302	20-4-43	13·7
Red Sindhi (67) ..	5400	360	25-12-42	21·0

Some of the best records reported in The 10,000 lb. Milk Club of India and The 7,500 lb. Buffalo Club of India are as follows.

Breed Zebu	Lactation yield in pounds	Fat test of the milk	Length of lactation in days	Date of calving	Maximum daily yield in pounds
Red Sindhi (100) ..	11,448	4·7	—	14-8-40	31·1
Sahiwal (99) ..	14,692	—	—	20-10-40	—
Buffalo					
Murrah (98) ..	9,155	—	457	29-11-37	—

CHAPTER XIII

THE ECONOMICS OF DAIRYING AND DAIRY BOOKKEEPING

The population of India may be divided into two economic groups, those in the high income brackets and those in the low. The former includes about 25 per cent or less and the latter about 75 per cent or more of the total. The proportion of the population which would classify economically as middle class is practically insignificant so far as any influence it may have on the total demand for goods is concerned. A demand is defined by economists as that quantity of an article which will actually be purchased by the public at a particular price. Demands for goods in India are, therefore, largely such that either large quantities of a commodity are required at a relatively low price by those with a low income or small quantities are required at a high price by those with a high income. The greater the range between the income of different members of a community and the greater the proportion of the total supply of a commodity that is demanded by those with the higher income, the higher the price of the commodity is likely to be and the larger the proportion of the population which cannot afford to buy it. The price of milk in India is entirely beyond what a very large majority of our people is able to pay.

Within the restrictions of any income pattern, even the one peculiar to the economy of India at the present time, demands may still be what economists would call elastic or inelastic. The demand for milk and milk products is, for the most part, elastic. It is a demand which changes inversely with the supply; in other words the price goes down as the supply increases and vice versa, other things being equal. The maximum amount of milk which would be purchased by the consumers with a low income, if the price were such that they could afford to buy it, is unknown; it may be considered unlimited in so far as India is able at the present time to produce that quantity. As the price increases, the quantity which will be purchased decreases until,

theoretically at least, it is possible for the price to be so high that it alone prevents the sale of any milk and milk products. An inelastic demand is one which involves a rather fixed quantity of goods regardless of the price.

The characteristics of an elastic demand differ in some respects from those of an inelastic demand. For example, one very effective method of disposing of excess stocks of a product for which the demand is elastic, such as disposing of a perishable product like milk before it spoils, is by reducing the price. Changes in price will not noticeably increase the quantity of a commodity that will be demanded in the case of an inelastic demand. Secondly, if it is desired that a quantity of a product, for which the demand is elastic, not be sold, it may be removed from the market or its price may be increased to a point at which the price alone prevents its sale. A product with an inelastic demand will be consumed or demanded in rather fixed quantities regardless of the price; the only effective method of preventing its sale, within the rather fixed quantity demanded, is by removing it from the market. Thirdly, if the quantity of a commodity which is offered for sale does not sell at a price which will pay the cost of production plus a small profit, a price which will do so is possible only by reducing the cost, that is by increasing the efficiency, of production. Should the price be increased in an attempt to recover the cost plus a profit, the quantity which would be demanded by the market, in the case of an elastic demand, would decrease. In the case of an inelastic demand, however, the price may be increased with little effect on the quantity of the commodity actually purchased by the consumers. Lastly, demands which are inelastic may cease to be so just as soon as substitutes appear on the market at a competetive price. Where only two products, for example, meet a single requirement of the public, the quantity of one which will be purchased, that is demanded, at a particular price will vary slightly with the price of the other, that is a degree of elasticity will then exist by reason of the availability of a substitute. The product for which the demand is definitely inelastic, therefore, has few if any substitutes, whereas that for which the demand is elastic may have several substitutes or the product may be a luxury which people may or may not consume, with no ill effects.

The demand for milk and milk products is elastic. The quantity demanded by the public will increase as the price goes

down in reference to the general price level and/or the income of the people. Milk and milk products are perishable. They must be sold within a certain fixed time, therefore, to prevent losses due to spoilage, although some of the products of milk, such as ghee and dried milk, may keep longer than others. There is, on the other hand, a considerable need for milk in India which is not being met. This tends to hold the price up in order to command more milk. The tremendous poverty of the masses, however, makes it impossible for them to buy milk with the result that the potential market remains a need, it is not an effective demand.

India has a potential market, that is, a need for milk which is almost unlimited. This need exists primarily in the villages where milk is produced. Village people do consume some milk, although they need very much more before it can be said that their diet is adequate. In areas near cities they sell a very large proportion of their milk for city consumption; in the more remote areas, most of the milk is used in making ghee. The labouring class in the cities neither produces milk nor has sufficient purchasing power to demand milk. In either case it will be necessary to increase the production of milk very greatly before the price will go down sufficiently to make it possible for these people either to purchase milk and milk products or withhold from the markets such portions of that they produce as will meet their needs. Their need for currency with which to purchase items for which the demand is comparatively inelastic, such as matches, salt and kerosene oil, is so great that they sell practically all the milk or ghee they have in order to obtain currency, undertaking, without success, to provide substitutes for milk in the diet.

The nutritional needs of our people involve a quantity of milk far in excess of that available at the present time. According to nutrition authorities, two, probably three times the milk now available should be consumed before it could be considered that adequate quantities were being utilized. There are several important ways by which to convert this need into a demand to make possible a more durable and a more successful dairy industry, as well as to improve the general health of the population by the provision of a better diet. Among these are, firstly, and possibly the most important, increasing the producing capacity and producing efficiency of the milk animals of the country by

providing more feed and by following improved breeding practices; secondly, increasing the efficiency of the processing and distribution of milk and milk products, one of the principal means of which is by increasing the efficiency of labour; thirdly, increasing the average real income of the people; and fourthly, subsidizing the dairy industry. The purpose of this text is to discuss certain aspects of the first and the second; a part of this discussion follows in the present chapter (see also Chapter XII). The third is largely outside the scope of our subject, except as it is effected by improvements in the dairy industry. The fourth is not advocated.

The Dairy Business

In the establishment of any business due consideration must be given to those factors which are liable to affect its success. One of the most important of these is the amount and type of experience which the management has had in such a business. One should *never go into business*, he should *grow into it*. Ghare (37) gives the same advice when he says. "To make a small beginning in business, and to develop it......in proportion to the experience obtained and the credit established, is always safe."

Other factors which must be considered are the quality and location of the land; the type, construction and location of the buildings; the producing capacity of the foundation stock, both cows and bulls, and the manner of replacing the herd, that is by further purchases or by raising young stock; the quality and the nature of the equipment; the quantity of materials and supplies to maintain and their availability; the amount of operating capital; the qualifications with regard to honesty and efficiency of managers, supervisors, and workmen; the reliability of the market and the possibilities of its further developing.

Land

The land chosen for the dairy farm should be well located, near a city and on a good all-weather road, if possible, to assure easy access to a market. The land should be obtained at as low a price as possible consistent with high fertility, good drainage and good soil texture and structure. Irrigation facilities should be available and the land should be consolidated, not scattered.

The purchase of land requires the investment of considerable

capital. Land which is owned by the business, however, may be improved by levelling, by the construction of canals, by fertilization and other means, which ultimately make it of greater value to that business. If the land is rented, the interest chargeable on the capital investment, the taxes and land improvements need not be paid directly by the business, but the rent which is paid by the business usually increases in proportion to the extent of the improvements. There are advantages to renting, but ownership is usually preferred.

Buildings

Inexpensive buildings are not always the most economical. They usually require so much more repairing that ultimately they will prove to be more costly than those built initially of more durable and therefore more expensive materials. Whatever buildings are constructed, whether they be those needed for the management of the land, for the management of the herd, or the dairy building itself, they must be durably and economically constructed. Economy must be considered from a long time point of view.

In locating the dairy building careful consideration must be given to several points, such as some of those mentioned by The Agricultural Marketing Adviser to the Government of India (16), Kelley and Clement (55) and Hunziker (47). A careful discussion of each point, unfortunately, is not possible here.

1. The locality should be satisfactory from a sanitary point of view.
2. Ease of access from as many sides as possible.
3. Value of the property.
4. Proximity to the milk and cream supply.
5. Proximity to the distributing centre of the markets.
6. Advertising possibilities.
7. Convenience to city water supply and electric power.
8. Avoidance of heavy traffic surroundings.
9. Good drainage and convenience of sewage disposal.
10. The availability of labour.
11. Opportunity for retail counter cash trade.

The type of business will determine the special considerations which will apply in each case, that is, a dairy farm located outside a city and producing all its own milk which is sold entirely as fluid milk will require a somewhat different type of dairy

building than that best suited for an ice cream factory which purchases all its raw materials and which is located in a very congested part of a large city.

The Dairy Herd

It has been shown that under certain farm conditions the zebu produces units of milk more economically than the buffalo, but that the buffalo produces units of butter fat more economically than the zebu (49). Under village conditions, as shown in Chapter XII, the buffalo produces more milk than the zebu, in fact about twice as much. The zebu is, for the most part, kept primarily for draft purposes. The maximum yields recorded for the two types of animals show that whereas the zebu produces considerably less milk on an average, it may be capable of excelling the buffalo. The greater variation in the producing capacity of the zebu, therefore, may possibly be taken as evidence that greater response in productivity may be expected in the zebu to the application of improved feeding and selective breeding than in the buffalo. This may be pure hypothesis, but the suggestion at least is apparent.

The buffalo is used in the greater part of India for milking purposes primarily because it produces milk from which ghee can be made more economically, because of the higher fat percentage, than from that of the zebu. This is indicated by the study quoted above. Dairies which are selling butter fat, that is ghee, butter, or cream, would find the buffalo the better animal for the milking herd, therefore, than dairies selling fluid milk and milk products whose value is more dependent upon the volume of milk produced than upon its fat content; the latter will find the zebu more economical. The animals studied by Joshi *et al*, however, included Jersey-Sindhi crossbred cows which, in this particular case at least, produced both units of milk more economically than the zebu cows and units of fat more economically than the buffalo cows. Crossbreeding, however, is not a practice which is recommended, except under very special conditions.

The particular product or products which are to be handled will influence the selection of the type of milk animals for the herd. In any case the best producers should be selected.

The choice of a breed will depend upon several factors, among which are :—1. the capacity of the breed to produce milk and/or butter fat at a low cost: 2. the availability of the

breed: 3. its popularity in the area in which it is to be maintained, which will influence the market for young stock, particularly male calves; and 4. the ability of the breed to withstand the local climate, pests and diseases.

False economy in the selection of a bull is a common criticism which may be justly directed against the management of a dairy herd. It seems to be commonly forgotten that approximately one-half of the producing potentiality of a calf is received from each parent. Furthermore, while a cow may normally be expected to produce between five and eight calves during her lifetime, a bull may produce as many as 300 to 500, possibly more; in each case one-half are heifers capable of entering the milking herd. Care in the selection of the breeding bull, therefore, is of considerable importance if the productivity of a herd is to be maintained, or increased. It may prove economical to pay several times as much for a good bull as for a good cow.

It is not always possible to purchase better animals or even to continue indefinitely to purchase good animals, as a means of improving or replacing the milking herd. Young stock, produced by selective breeding, must be raised for this purpose. The cost of raising dairy stock will depend upon the method used. Should calves be raised by the natural nursing method it is impossible to assess accurately the cost of the milk they consume for it cannot be measured satisfactorily. The artificial nursing or pail feeding methods make it possible to calculate the actual cost of the milk consumed by the calf since it may be weighed before being fed to the calf. The grain and fodder consumed may be determined whatever the method of feeding milk. Only when the feed costs are known it is possible to calculate the cost of raising the calf. An acceptable method of determining the capital value of the animal on entering the milking herd is to use the cost of all materials and services consumed in raising it from birth, when it may be valued at a rupee or so at the most, to the date on which it freshens for the first time and enters the milking herd.

Other Capital Items

Other items which involve setting aside a certain amount of money in order that the business operate satisfactorily are equipment; stocks of supplies required in the processing of the milk and the manufacture of milk products; stocks of unsold goods; and an operating fund.

The equipment must be serviceable and durable, yet as economical as is possible. As is true of buildings, it may not be economical to purchase low priced equipment, for it may require repairs sufficiently soon and frequently that the expense is ultimately greater than it would be were more costly equipment purchased initially. Very little dairy equipment is made in India; the only other source is by importation which is extremely expensive in many cases. Under these conditions certain kinds of equipment will be found to be economical both initially, although of poorer quality than that available by importation, and ultimately, because of the great expense of importation. It seems reasonable to hope, however, that considerable improvement in the quality of that which is, and development of the manufacture of that which is not, now manufactured here can be expected in the near future. Stainless steel equipment, for example, is rather expensive initially, but there is usually very little if any expense necessary for repairs for many years.

The amount of capital required to maintain a suitable stock of supplies will vary with their cost and the quantity required. For purposes of economy the stock of supplies should be as small as possible, consistent with the needs of the business and the ease with which they may be replaced as utilized. The normal operations of the business should never be held up because of the lack of supplies if this can be avoided. A well organized store room in the charge of a storekeeper who is alert to the needs of the business should prevent this, provided the storekeeper is permitted to make purchases as and when he feels they are needed. Whatever supplies are kept on hand involve the investment of money, however, which may be recovered only when those supplies are utilized in the business.

Stocks of unsold products may sometimes involve considerable sums of money. The quantity of dairy products which may be in stock at one time will vary with the products involved. Tinned butter, dried milk, condensed or evaporated milk and ghee may be held for longer periods than other products. With adequate refrigeration, packet butter, ice cream and cheddar cheese may also be held for a while. Of these products, only cheese must be held for ripening to improve its market value. Milk products may be produced in large quantities during the season when milk and cream are available at a low price and then held for sale at a time when these raw materials are ex-

pensive, at which time the market is more favourable. Such products as *dahí*, *khoá*, *chhená* and soft cheese are highly perishable so that they may not be kept more than a few days, even with proper refrigeration. Products which are stored must sell for sufficiently more to pay for any losses, deterioration and interest on the capital invested in them. Large quantities of such products as cheese, at Rs. 2-0-0 to Rs. 3-0-0 a pound; butter, at Rs. 1-8-0 to Rs. 2-0-0 a pound; or ghee at Rs. 2-0-0 to Rs. 4-0-0 a pound; may involve considerable investment. Whether or not products are intentionally stored and held for a period of time to take, or in the hope of being able to take, advantage of a better market, there is always some delay between the manufacture of the product and its sale. During this time interest on the investment the product represents must be charged to the business.

Money invested in the products of the dairy is recovered, except for credit sales, in whole or in part at the time they are sold. If only a part of that investment is recovered the business suffers a loss; if the sum recovered is in excess of the investment a profit is realized. A business can be expected to exist only so long as it pays all its costs; it will be successful only if it returns a profit in addition. A business which is subsidized may survive and give the appearance of being successful, only so long, however, as the subsidy continues. The subsidy may consist of credit or it may involve the donation of services, such as human labour, in cases like that discussed by Warner and Joshi (110) in reference to the production of ghee in the villages where it is felt that the provision of a commodity by one method is more desirable, although not necessarily more economical, than by another. In the case of credit sales, the investment continues to be the responsibility of the business until payment is received. Two expenses accrue in the case of credit sales which add to the investment involved, namely, the continued expense of interest on the investment and the losses due to failure to recover the value of a certain proportion of the products.

The greater the time during which capital is invested in stocks of supplies or goods, the greater the amount of capital required to keep the business operating. Rapid turnover, as it is called, of capital, that is, frequent recovery of the investment in goods by their sale, reduces the operating capital required; the expense of interest on this capital is thereby reduced.

Employees

Sinha (87) states that the chief enemies of the dairyman in the operation of his business are the employees. He points out, however, that he refers not solely to those in the paid service of the dairyman but also those in the paid service of his customers. He refers to the lack of integrity and dependability in the managers and supervisors contributing much to the failure of the workmen to serve satisfactorily.

Undoubtedly the first and most important requirement of all employees is honesty. This is particularly true of those who handle the milk or milk products and the money. Dependability is another important qualification which must be found in all persons on whom responsibility is placed. The manager must be especially honest and reliable and have adequate professional experience and ability to supervise the details properly. He must be alert at all times to possible losses and continuously seeking means and methods of economizing the production of the best possible quality in his product. He must be considerate of his workers, his directors and his customers. Supervisors must be honest, reliable and well trained in all phases of the work for which they are responsible. They must fully understand those who work under them and must not make demands which are unreasonable. They must be firm in their demands of those responsible to them, however, in order to assure the work being done properly as required. All other employees must be honest, trustworthy, willing, capable of hard work and intelligent. All employees must be paid adequately to encourage reliability and accuracy in their work.

The Market for Milk and Milk Products

It is estimated that the milk produced in India is utilized in the following manner (16):—

Consumed as fluid milk	28·0 per cent.
Converted into ghee	57·0 ,, ,,
Converted into *khoá*	5·0 ,, ,,
Converted into *dahi*	5·2 ,, ,,
Converted into factory butter	1·7 ,, ,,
Converted into ice cream	0·3 ,, ,,
Converted into fluid cream	0·4 ,, ,,
Converted into other products	2·4 ,, ,,

A reasonable proportion of the milk produced in rural areas is consumed in urban areas where only a small proportion of our

people live and where 4·75 per cent of all milk is produced. It is obvious, therefore, that the consumption of milk by urban people is greater than by those living in the villages. Consequently, the greatest potential market for milk is in our rural areas. At the present time, however, there is very little buying and selling of milk or milk products among the village people, other than that which is directed toward the supply of these commodities to cities and towns.

Three geographical zones exist so far as the utilization of milk is concerned. Others may be mentioned, but they involve only very small quantities of milk. The first of these is the urban zone. Whatever milk is produced in this zone is consumed therein. In addition to this, considerable quantities of milk and milk products are demanded from the other zones. The second is the zone immediately surrounding urban areas and in which large quantities of milk are produced. Most of this milk is transported to and marketed in the first zone; only a portion of the milk produced here is converted into milk products. The third zone comprises the remote rural areas in which almost all of the milk which is marketed is first converted into ghee. There is a small area, covering usually only the outer edge of the second zone and the inner edge of the third, in which *khoá* is made seasonally in large quantities. There is also that area in which whole milk is purchased by butter manufacturing companies; the milk being separated, the skim made into casein and the cream shipped to the butter factory. This area is usually found within the limits of the third zone mentioned.

The increasing tendency to transport milk by motor and rail is changing the boundaries of these zones, particularly that between the second and the third. This may provide milk to meet a need which exists in the first zone, but care must be taken that it does not deprive those producers from whom the milk is obtained from that amount which they and members of their families now consume, either as fluid milk or one of the products of milk, particularly *maṭṭhá*.

What the economist calls an effective demand does not always represent the quantity of a particular commodity which is actually needed by a community. A business is not successful unless it not only pays all of its expenses but returns a profit as well. It may be possible to operate a successful business by converting a product, for which there is a very great need but

not an effective demand, into a product for which there is an effective demand. If the need for the latter is as great as the former, the business is undoubtedly justified, if the need for this product, however, is considered to be less than the need for that utilized in its manufacture, there will be those who question the practice. There may be cases, however, in which the conversion of a small percentage of the product with the greater need into some other may pay sufficient profit that the business is able to sell the remaining and larger portion of that which is greatly needed at cost or even less.

Prior to the war, milk sold for 7 seers and ghee for 14 *chhaṭáṉk* for a rupee. The outturn of ghee from such milk is about 5 per cent; the outturn of *maṭṭhá*, in terms of whole milk equivalent, is about 30 to 33 per cent. One hundred seers of fluid milk would sell, under these circumstances, for Rs. 14-4-8, whereas the ghee made from this milk would sell for only about Rs. 5-10-6. Should the outturn of ghee be 6 per cent, as it may be from buffalo milk, the return would be Rs. 6-13-8. To give the same return for milk and ghee the ratio of the price of milk in seers for a rupee to that of ghee in *chhaṭáṉk* for a rupee would have to be about 1: 1·25 at 5 per cent outturn of ghee, or 1: 1·04 if the outturn of ghee were 6 per cent. These figures, however, do not take into account the value of the *maṭṭhá* nor the expense of converting the milk into ghee and distributing it as compared to processing and distributing the milk. It may be unwise, therefore, to consider this particular ratio of the two prices as a reasonable comparison between the value of the two products. A comparison of this type may be used effectively, however, to indicate whether it would be more profitable to convert milk into ghee, taking into account the cost of making ghee, the possibility of selling or using the *maṭṭhá* as a food and other items of cost and income, or to sell it as fluid milk.

Prices at the present, in some places, are 2½ seers of milk or 4 *chhaṭáṉk* of ghee to a rupee. This is a ratio of 1: 1·6 which indicates that it is undoubtedly more profitable to sell fluid milk than convert it into ghee. A very large part of the milk produced in the country, however, is found in areas where there is no market for fluid milk, that is our third zone of utilization. The manufacture of ghee is unquestionably the purpose for which such milk should be used, apart from using it for human food purposes.

The manufacture of butter gives skim milk and buttermilk as by-products. Buttermilk has little value except as stock feed, that is for pigs and chickens. If dried, it may be used in grain mixtures for any class of farm animals. No buttermilk is dried in India, however, for it is not available in quantities which would make it profitable at the prices at which dried buttermilk could be sold. It is, unfortunately, usually discarded, except where a piggery is operated in connection with the butter factory. There are cases where small quantities of buttermilk are used for food purposes by the poorer people, and it is good that this is done. Skim milk is another problem. Very large quantities of this product are available in certain areas. Skim milk is generally utilized either in the fluid milk market, or for making *khoá*, *dahí* or casein. Small quantities are used for drinking purposes, or for feeding to pigs and chickens. Whatever income there may be from skim milk helps to contribute to the total for milk utilized in the making of butter.

Apart from any incone there may be from the skim milk, or possibly the buttermilk, the income from the butter made from a quantity of milk is usually smaller than that for the same amount of milk if sold as fluid milk. The butter outturn from milk is between 5·0 and 7·5 per cent, depending upon the fat content of the milk, the fat losses during the manufacturing of the butter and the fat content of the final butter. Roughly, 100 seers of 5 per cent milk will yield 10 seers of 50 per cent cream from which 6 seers of butter may be made. This is an outturn of 6 per cent of butter from such milk. If milk sells for 7 seers to a rupee, butter should sell for at least Rs. 2-6-0 a seer to give the same return. The ratio of the retail price of milk in pies per seer to the retail price of butter in pies per seer, to give about the same income from each for a quantity of milk, should be about 1 : 16·6. A greater outturn of butter than 6 per cent will reduce this ratio, whereas a lower outturn will widen it. As the ratio diminishes it becomes less profitable to make butter than to sell milk. At the time the price of milk was 7 seers to a rupee in a market with which the author is familiar, butter was selling for Rs. 1-8-0 to Rs. 2-0-0 a seer. That gives a ratio of the price of milk in pies per seer to the price of butter in pies per seer of between 1 : 10·5 and 1 : 14·0; at the present time milk sells in that market for 2½ seers to a rupee and butter for Rs. 4-8-0 a seer, a ratio of about 1 : 11·2 or 76·8 pies : 864 pies. In both

cases it is more profitable to sell milk in that market than to convert that milk into butter.

One more comparison may be made to further illustrate the use of this method of determining the comparative returns which are possible from the different products of the dairy. At the present time, domestic cheddar type cheese is selling at retail for as much as Rs. 6-0-0 a seer (Rs. 3-0-0 a pound). The yield of saleable cheese from 4 per cent milk is about 9·5 per cent. The present ratio of the retail price of fluid milk in pies per seer to the retail price of cheddar cheese in pies per seer, with milk at 2½ seers to a rupee, is about 1 : 15·0 or 76·8 pies : 1152 pies. To give approximately the same return from either milk or cheese, however, this ratio should be about 1 : 10·5 or 76·8 pies : 806·4 pies. In other words, the present prices for cheese give 1152 pies minus 806·4 pies or Rs. 1-12-10 more for each seer of cheese than would be obtained from the milk from which it is made, that is about 10·6 pounds, were it sold at 2½ seers to a rupee. This is not all profit, however, for the cost of manufacturing and distributing cheese is considerably greater than the cost of processing and distributing milk. There is, on the other hand, very likely a small profit on the milk at 2½ seers to a rupee.

Ratios between other products may be determined as a guide to the management of the dairy business. Where a market exists for two or more products such ratios, determined frequently, will indicate which of the products should return the largest profit. In determining such ratios as may be desired all items of cost must be taken into account, without this they will be incorrect and will misguide the management. The ratios discussed here do not take into account the costs involved in converting milk into the product concerned. Ratios between the cost of milk as delivered to the customer and the retail value of that milk will show immediately whether there is any profit in handling milk; similar ratios may be useful for other purposes. Those of the kind just described, however, will show which product is most profitable, provided all costs are taken into consideration.

The Cost of Milk Production

Very limited information is available to show the cost of producing milk in organized herds, and practically no data exist regarding the production of milk under village conditions. Two sets of figures are available, however, of which the first (16) deals

with the cost of producing milk on some government farms in the Punjab. Supervision and interest on the investment, both of which may be rather important items of costs, are not included. The figures for one pound of milk and for one pound of butter fat are shown below. Feed costs are based on the 1932 prices.

	Red Sindhi zebu	Ferozepore Sahiwal zebu	Murrah buffalo
(a) Cost per pound of milk ..	pies	pies	pies
Feed during the lactation ..	4·48	3·88	5·68
Feed during the dry period ..	1·42	1·01	1·96
Depreciation on stock	2·01	1·33	2·20
Labour (excluding supervision) ..	1·51	0·94	1·30
Total ..	9·42	7·16	11·14
	as. p.	as. p.	as. p.
(b) Cost per pound of fat	15 8·4	12 11·6	13 3·1
(c) Number of animals studied ..	84	51	294
(d) Average lactation yield (lbs.) ..	3050	6000	3100

Joshi *et al* (49) give a much more detailed statement of the cost of producing milk and butter fat. Their figures, as those quoted above, apply to farm conditions. Practically nothing seems to be available so far on the cost of producing milk in the village where conditions are so very different. The figures given by these workers are summarized in the following table. The first three items are in rupees; the following ones, except for the average production of milk, are in per cent of the total cost.

	Red Sindhi	Jersy-Sindhi	Murrah
Cost of maintaining one cow for one year	236- 2-4·7	256-14-1·9	303-6-11·3
Cost for 100 pounds of milk ..	7-12-1·9	5-11-3·7	8-3-10·1
Cost for 1 pound of fat	1-9-6·9	1- 2-0·3	1-3- 0·7
Cost—			
Roughages	30·06	27·68	39·90
Concentrates	23·76	33·06	21·81
Light	0·88	1·03	0·68
Water	1·99	1·84	1·89
Labour	6·93	6·36	5·39
Supervision	2·37	2·18	1·84
Equipment depreciation ..	0·74	0·68	0·85
Equipment repairs	0·96	0·88	0·74
Miscellaneous	3·08	2·83	2·40
Bull services	1·72	1·43	1·01
Depreciation on cows ..	15·74	12·98	15·78
Commercial	14·24	11·53	10·72
Credit—			
Manure and calf value ..	2·53	2·53	2·78
Average production during the year (lbs.)	3043·2	4501·3	3682·4

The figures showing cost in per cent of the total equal more than 100 by the amount of the credit, that is they are shown in per cent of net commercial cost, or the total cost exclusive of the credit for the manure and the calf. The percentages apply to the cost of maintaining a cow for the year, of producing 100 pounds of milk or of producing one pound of butter fat. These figures, it must be remembered, are correct only for conditions at the time and in the herd from which they were derived. They will indicate, however, approximately what may be expected under other farm conditions, at other times as well. They show the greater utility of the buffalo cow as a producer of milk for the ghee market, of the zebu cow as a producer of milk for the fluid milk market, and of the crossbred cow as a producer of milk for either type of market.

The cost of handling one maund of milk, that is between the producer and the consumer, are reported for 1939-40 for the Lucknow Co-operative Milk Supply Union, Ltd., the organization of which is discussed in Chapter XIV (16). These figures involve 11,450 maunds or nearly one million pounds of milk. They are given in the following table.

	Rs.	a.	p.
1. Assembling charges from villages to the rural depots	0	6	1
2. Transportation charges by motor and tonga from rural depots to Lucknow ..	0	4	10
3. Distribution charges on bicycle (10 per cent in bottles and 90 per cent in cans) ..	0	6	1
4. Processing expenses, rent of building, printing and stationery, legal expenses, etc. ..	0	9	0
5. Supervision charges—			
(a) At producing villages	0	1	0
(b) At rural depots	0	1	9
(c) At processing and distributing centre	0	3	8
Total handling cost per maund ..	2	1	2

This cost of Rs. 2-1-2 a maund is equal to 4·85 pies per pound. The commercial cost of handling and distributing 2,15,550 pounds of fluid milk, of which 98·7 per cent was in cans and only 1·3 per cent in bottles, was 5·3 pies a pound during 1943-44 at the Allahabad Agricultural Institute Dairy. This milk was not pasteurized or heated. It was mixed milk consisting of

between one-seventh and one-fifth buffalo milk and the rest that of the zebu and crossbred cows.

Dairy Bookkeeping

Bookkeeping involves the establishment and maintenance of a system of records showing the assets, liabilities, proprietorship, items of income and items of expense of a business. The nature of the business and its size will determine, to a considerable extent, the kind of accounting system to employ. It may be simple or extremely detailed according to the desire of the management and the requirements of the business. The more elaborate the system the more expensive it is to maintain, yet the more information it will give at any time. Small businesses usually employ simple accounting methods; larger businesses, the larger and more complicated methods. Whatever system or method of accounting or bookkeeping employed, it should show the financial condition of the business at any time; it should indicate whether a profit is or is not being realized and the amount involved. If the system is sufficiently detailed, it will show reasons for the particular financial condition involved and which products or operations are responsible.

During a particular period of time, whenever the total expenses exceed the income a loss results; when the income exceeds the expenses, a profit is realized. The simplest system, therefore, has only two accounts, namely, that for income and that for expense. A slightly more detailed system includes several sub-accounts or divisions of the income and expense accounts. These divisions are expense-wise rather than product- or operation-wise. That is, the cost of labour, for example, is all listed in one labour account under a larger expense account, rather than being subdivided, such as into labour for making butter, labour for pasteurizing milk, etc., or being divided into labour for churning, labour for washing the butter, labour for working the butter, etc. Such extensive sub-divisions of accounts characterizes a third system, that of cost accounts. In this system the items of cost are divided into very many sub-divisions in order to show the amount for each item of expense on one product separate from the same item of expense on another, or to show the amount of each item of expense on one operation as distinct from the amount for the same item for another operation. Cost accounting is not commonly used in dairies in India.

Assets

Assets include anything owned by an individual or business which may be used for the payment of debts, that is which has value. They consist, therefore, of land, buildings, equipment, stocks of supplies, stocks of unsold goods, accounts receivable and any reserve accounts which may be maintained. In some instances good will is considered an asset in that it may be sold at a value should the business be transferred by one management to another. This, however, is not a universal practice and the difficulty of accurately assessing its value is so tremendous it will only be mentioned here.

Inventories—A record of any kind of assets, together with the values of the items concerned, owned by a business is called an inventory. The usual inventories maintained by a dairy business are those for land, buildings, equipment, supplies and unsold goods. The list or record of accounts receivable is not usually considered an inventory, but may be included as such according to the definition just given. There may be two kinds of inventories for buildings and equipment, that is, that containing all items and which serves as a stock record as well as an inventory, and that which contains only those items which are not completely depreciated, that is, which are still considered of value or against which a replacement fund is in the process of being accumulated, but which is insufficient fully to replace the item. One record each of the buildings and equipment may be sufficient provided items which have been completely depreciated are continued on the list at very little or no value so long as they are still in existence and in the possession of the business. Inventories of stocks of supplies and unsold goods are fundamentally stock records although the values of all items are shown to aid in determining the capital invested in unused supplies, and the cost of those consumed during each accounting period as well as the capital value, usually actual cost of production, of unsold goods.

Interest on Capital—A charge for the use of money invested in the business is legitimate. This involves the money invested in all assets. Since money may be invested outside the business in any of a great variety of different ways, any one of which will pay for the use of that money, it is a common practice to expect a business to pay for the use of its capital. If the

money is provided from the personal savings of the proprietor of a privately owned business, interest may not be charged; the profit, if any, arising from the operation of the business being considered as constituting the interest received. If the money is borrowed from a bank or other source or is made available through the sale of shares of stock, the interest must certainly be charged the business for it must be paid. The rate of interest will depend upon the current rates payable in the local money markets.

In the case of inventories of supplies, unsold goods, and of the accounts receivable and reserve funds, the interest may be charged on the value at the beginning of the accounting period, the value at the end of that period or the average of the two values.

Depreciation—The real value of certain capital items such as buildings and equipment, does not remain the same at all times. These things deteriorate or wear out during use and must eventually be replaced. Depreciation is a deduction from the value of a thing, made periodically because of its diminishing value caused by wear, tear and antiquity (35). The rate of depreciation is usually a fixed per cent of the original cost, value or estimated worth of the item concerned. Charges for depreciation are payable each accounting period by the business. Land is not, nor are stocks of supplies, stocks of unsold goods, accounts receivable and other assets, except those mentioned above, usually depreciated. Interest is also charged on the remaining value of those items which are depreciated. In the case of accounts receivable, a small charge may also be made regularly for a reserve for bad debts which are accounts that are actually receivable but which in fact will not be received.

The common rates of depreciation for certain items on the dairy farm or in the dairy are listed on page 292. These rates will vary with the life of the item concerned. They are fixed so that the value as indicated in the inventory, that is the nominal value, is as nearly as possible equal to the price for which the item could be sold, that is its real value. The figures are taken largely from Mortensen (74).

Young dairy animals, prior to first parturition in the case of females and first service in the case of males, appreciate, that is increase in value, rather than depreciate. For this reason a separate inventory may be kept of them showing the value of

each head at the beginning and at the end of the accounting period. Their value is an asset on which interest must be charged.

Item	Annual rate of depreciation in per cent of the original cost.
Ice tanks and cans	25
Laboratory equipment	10
Horses, wagons, harness	15
Motor cars	25 to 33·3
Machine shop equipment	10 to 20
Scales, tanks, pumps	15
Motors (electric)	15
Pasteurizers	12·5 to 15
Churn	20
Cans and pails	33·3
Farm machinery	10 to 12
Milk stock	16·6 to 33·3
Brick and cement buildings	3
Office furniture	7
Typewriters	15
Plumbing fixtures	5
Power freezers	10
Boilers	6
Steam and gas lines	8
Steam engines	8
Electric equipment	10
Ammonia compressor	8

Accounts Receivable—A business may require cash payment for all goods which it sells or it may allow credit to the purchaser, that is allow payment at a subsequent date. Between the actual transfer of the goods and the receipt of payment for those goods their sale value is receivable. The allowing of credit to purchasers may sometimes make sales possible which would not otherwise take place. This increases the volume of business which is usually desirable. On the other hand, the practice involves a certain amount of expense in maintaining careful records of outstanding bills, in sending notices to the debtors and in actually collecting the amounts involved. Another item of expense, however, which at times may amount to a noticeable proportion of such credit sales results from the

failure of the debtor to pay the amount in full. Such bad debts are an expense which the business must meet. Where credit is allowed on purchases it is good practice to set aside a small reserve to cover bad debts.

Reserves—Reserves consist of sums of money which are held to cover uncollectable accounts receivable for bad debts, in depreciation funds, bank balances in the operating account and any other sums which are set aside and maintained to meet expenses which shall arise during the normal operation of the business concerned. Such sums may, in case they are rather large, be invested by the business and interest earned on them. Interest is charged the business for them, however, although this may be offset in whole or in part by the interest they earn elsewhere.

Liabilities

Liabilities are what are owed by the business to its creditors, or what the business is liable to pay. Among these are such items as provident or retirement funds for the employees, unpaid bills or accounts payable, loans payable, bonds payable, mortgages payable or unredeemed stock. The money invested in a business by its owners may be considered a liability, but this amount must be shown separate from what is owed to others, particularly if the law should support prior claim of nonowner-investors to any assets of the business. To distinguish between money invested by the owners and that invested by others the former is called proprietorship, net worth or some other appropriate term (20). The amount of the proprietorship is determined by the difference between the assets and the other liabilities. This amount changes frequently and may do so without previous consent of the owner, whereas liabilities may change only with the previous consent of the creditor.

The assets and liabilities of a business are affected by the income and the expense items which are continuously changing. Such changes occur with every sale and with every unit of goods or services utilized. The balance between these two nominal accounts at the end of an accounting period will affect the balance of the real accounts, that is, the assets on the one hand and the liabilities plus proprietorship on the other. The income and the expense accounts, therefore, must eventually be closed into the proprietorship account to show the financial condition of the business.

Income

Income is realized from any transaction which increases the proprietorship of the business, that is the sale of goods or services. In the operation of the dairy business income will arise from the sale of livestock, crops, dairy products and miscellaneous items. As has been stated, should the money held in reserve for one purpose or another be invested outside the business there may be income from its use elsewhere, although such funds, except possibly provident funds, are commonly reinvested in the business itself. There may be other sources of income peculiar to a particular business. If so, they must be shown.

In the dairy, income is realized almost exclusively from the sale of milk and various milk products. A careful record of such income is essential, although it may not be desirable to keep separate records of the income for each product; they may be grouped in one master income account, particularly in the smaller dairies. The accounting system should include provision for the return of goods, actually entered as sold, for which money must be refunded.

Expenses

Amounts set aside in reserves, amounts set aside for replacement, amounts actually spent on labour, lights, water, raw materials, repairs and any other goods and services involved in the operation of the business are included among expenses. In other words, any transaction which decreases proprietorship is an expense. All expenses may be entered in one master account, in the simpler system of bookkeeping, or they may be entered in subsidiary accounts item-wise. The accounts, reported by Joshi *et al* (49), which are involved in the production of milk in the herd studied have been listed above under the discussion on the cost of milk production. The number of accounts which may be used and their names will be determined in each case by the nature of the business and the desires of the management. They must, however, show all costs involved before they are complete. In cost accounting each item of expense may be further divided product- or service-wise in order that the desired details of costs be shown.

Double-entry Bookkeeping

In the establishment and operation of any business, money

must first come in before it can go out, that is assets must first increase before they may decrease or before liabilities may increase. Remembering that the income and the expense accounts are both nominal or explanatory accounts of the proprietorship account, which is in turn actually a liability, it is seen that there are only two things in a business, that is assets and liabilities; three real accounts are used for these, namely, assets, liabilities and proprietorship. These two aspects of the financial organization of any business are always equal. A method of bookkeeping may show all assets on one side of the page and all liabilities on the other, thereby making it easy to check the accuracy of the accounts at any time by merely determining whether the totals of the two sides agree. All accounts, that is assets, liabilities, proprietorship, income and expenses, may only increase or decrease. Double-entry bookkeeping is defined by Cole (20) as a bookkeeping plan which records any changes which take place in the values of assets and liabilities. Accounts are debited when figures are entered into them on the debit or left side, and credited when figures are entered into them on the credit or right side (20 and 35).

According to Cole, the assets are always on the left side, liabilities always on the right of the double entry account; in other words, increases in assets and decreases in liabilities are always debited, decreases in assets and increases in liabilities are always credited. Proprietorship functions in accounting as a liability for it is in reality a liability of the business to the owner rather than to some one else. Consequently, when assets increase, proprietorship may increase. Since the two sides of the accounts must be equal and increases in assets invólve increases in liabilities or proprietorship, debits in assets may be offset by credits in proprietorship.

The income and expense accounts, are explanatory or nominal accounts, describing what is happening to or the causes of changes in proprietorship. Any increase, therefore, in income is offset by an increase in proprietorship because income increases this liability of the business. Likewise, an increase in expenses is offset by a decrease in proprietorship because expenses decrease this liability.

According to the above plan of offsetting one account by a change in another, Cole lists nine transactions which he states

are the only ones possible in double-entry bookkeeping. These transactions are listed below.

Increase in assets offset by	..	1. Increase in liabilities. 2. Increase in proprietorship. 3. Decrease in other assets.
Decrease in assets offset by	..	3. Increase in other assets. 4. Decrease in liabilities. 5. Decrease in proprietorship.
Decrease in liabilities offset by	..	4. Decrease in assets. 6. Increase in other liabilities. 7. Increase in proprietorship.
Increase in liabilities offset by	..	6. Decrease in other liabilities. 1. Increase in assets. 8. Decrease in proprietorship.
Decrease in proprietorship offset by		8. Increase in liabilities. 5. Decrease in assets. 9. Increase in other proprietorship accounts.
Increase in proprietorship offset by		9. Decrease in other proprietorship accounts. 2. Increase in assets. 7. Decrease in liabilities.

In order to show graphically the accounts discussed thus far and to indicate the side of the book on which the different entries are to be placed, Cole gives the following.

Assets	
Increases	Decreases

Liabilities	
Decreases	Increases

Proprietorship	
Decreases	Increases

Income	
(Used only for correcting and in closing.)	Always credit.

Expenses	
Always debit.	(Used only for correcting and in closing.)

Journal

As each transaction occurs it is recorded first of all in the journal. This entry should show the accounts involved, the debits and the credits which are to be made and the nature of the transaction. The journal entries are supported by receipts, cash memos, vouchers, etc., and are entered chronologically. This book is a daily register, day book or book of original entry. The process of making entries in this book is called journalizing. The form for the journal is as follows.

Page No.

Date	Transaction	LF	Debit	Credit
			Rs. a. p.	Rs. a. p.
Year, Month and day	Account to be debited .. Account to be credited* .. Description of the transaction	**		

*The account to be credited is indicated by indenting as shown.
**Enter here the ledger folio, that is, the page of the ledger to which the item is transferred or posted.

Ledger

The ledger contains a condensed and classified record of all transactions of the business. It is to the ledger that all entries in the journal are transferred; it is the final record of all transactions. Only entries which have first been made in the journal may be placed in the ledger. The form used for the ledger is shown below.

Ledger account name. Page No.

Date	Item	JF	Debit	Date	Item	JF	Credit
			Rs. a. p.				Rs. a. p.
Year, month and day.	Very, brief statement of transaction.	*		Year, month and day.	Very brief statement of transaction.	*	

*Enter here the journal folio, that is, the page of the journal from which the item is transferred or posted.

Posting

After the journalizing is completed all items and amounts must be posted to, transferred to or entered in the ledger. This process is called posting. All amounts which are posted from the journal to the ledger are entered in the latter in the same column, that is debit or credit, as that in which they were found in the journal. The separate accounts in the ledger to which items are to be posted should be indicated in the transaction column of the journal so there will be no mistake. The necessary reference to page numbers must always be given in the folio columns of the two books to serve as an index of the particular location of any entry in one book to its location in the other.

Trial Balance

After all the postings are complete for the accounting period the ledger accounts are closed, that is, the two sides are totalled and the difference is indicated on that side of the book in which the excess appears. A debit balance, for example, indicates that the total of the debit items in the ledger account in question exceeds the total of the credit items. All ledger account headings are listed in a separate page of the journal immediately following the entries for the period involved. Opposite these headings the debit or credit balances from each ledger account is entered in the debit or credit columns respectively. The two columns are then totalled. If they agree with other and with the respective totals in the journal the books are known to be in balance. The entries may or may not have been properly made, however, although the chances are rather good that they have been if the books balance at this stage.

The trial balance is intended as a test of the following formula (20).

$$A+E=L+P+I$$

in which A is the assets; E, the expenses; L, the liabilities; P, the proprietorship; and I, the income.

Profit and Loss Account

After the postings and balancings are complete in the ledger another summary account must be prepared which will show the total decrease, that is debit, or increase, that is credit, in the proprietorship account. This involves setting together the balances

from each of the income and expense accounts in the ledger. This is commonly done on the form used for the ledger, the difference between the debit and credit column totals being the net loss in proprietorship, if a debit balance, or the net gain in proprietorship, if a credit balance.

The use of the profit and loss account greatly reduces the number of entries which must be made in the proprietorship account, for only one figure, representing the net profit or the net loss, is involved. Without the profit and loss account it would be necessary to transfer the balance in each income and each expense account in the ledger to the proprietorship account.

Balance Sheet

The balance sheet is a statement of the balances in the three real accounts, namely, assets, liabilities and proprietorship. All ledger accounts must be closed and the balances in the nominal accounts carried to the profit and loss account, the balance from which is transferred to the proprietorship account. Following this the balance of each real account is transferred to the balance sheet. Different authorities suggest different forms for this statement. Whatever the form used, if it is in keeping with the idea of double-entry bookkeeping, it must show the assets and any debit balance in proprietorship account on the debit side and the liabilities and any credit balance in the proprietorship account on the credit side. A business is said to be solvent if it has sufficient assets to cover all liabilities, that is, when the assets exceed the liabilities.

Further Suggestions

Space does not permit a more detailed discussion of the principles of bookkeeping and of the various records which may be found useful in the operation of a dairy business. Information in the literature dealing with the accounting problems of a dairy farm and/or a dairy business specifically is limited. The student is advised, therefore, to refer to the literature cited in this chapter for further details. He will find many records useful which are not discussed either in this text or in the literature referred to. Experience with the accounting involved in the operation of his business will show him what further records might be effectively employed, and how he should employ them.

CHAPTER XIV

MARKETING OF MILK AND CO-OPERATIVE DAIRYING

Of the milk produced in India, 49·1 per cent or 3660·9 lakh maunds are produced by zebus, 47·5 per cent or 3534·8 lakh maunds by buffaloes and 3·4 per cent or 251·2 lakh maunds by goats. Not all of this milk is hand-drawn, however, as some of it is consumed by the calves or kids; the amounts so consumed by the young of these animals are estimated to be 763 lakh maunds, 332 lakh maunds and 59 lakh maunds respectively. Of the total hand-drawn milk, the zebu produced 46·0 per cent, the buffalo 50·9 per cent and the goat 3·1 per cent (18).

About 4 per cent of the zebu cows are kept in urban areas where they produce 146·4 lakh maunds of milk and about 5·9 per cent of the buffalo cows are found in urban areas where they produce 208·6 lakh maunds of milk. Approximately 4·75 per cent of all milk is produced in these areas (18). Owners of milk cattle in urban areas, that is, cities or towns having a population of 5,000 or more, are of two types. One keeps one or two cows strictly for the supply of milk for his family. About 25 per cent of the animals kept in such areas are owned in this manner. The other type of urban owner maintains several animals, sometimes over 100 but usually fewer, the milk from which is sold. Not all such owners maintain their cows in *gośále* or cattle sheds; many are kept in private yards, in open lots or even on the streets. A certain number of cows producing milk in urban areas are maintained in charitable institutions, called *piñjarápol*, at least one of which exists in nearly every city.

Ninety-five per cent of the milk producing animals of India are owned and maintained in rural areas. Frequently one person owns a fairly large number, although only a few animals per owner is more common. The milk produced is utilized for consumption in the home, for sale as such or for the manufacture of milk products such as ghee and *khoá*. Nearly 60 per cent of India's milk is converted into ghee. The *maṭṭhá* or buttermilk

obtained as a by-product is consumed in the home. Large dairy farms are nearly always located near yet outside the limits of cities or towns. Milk produced in such places, therefore, is largely included in that from the rural areas.

Quality of Milk

The quality of market milk in India is generally poor. Several reasons may be given for this, among which are the lack of knowledge of the proper methods of handling milk, improper sanitation of the utensils, the practice of adulteration and the lack of refrigeration. It was stated in Chapter VI that milk usually has a very low bacterial count when drawn from the udder. In cases in which the udder is diseased, the bacterial content of the milk may be exceedingly high. The possibility of milk being of a poor quality at the time it is produced by no means accounts for its condition as found in our markets. Three of the factors named above, namely, the utensils, the method of handling the milk and adulteration, no doubt contribute more to the poor chemical and poor bacteriological quality of our milk supply than any others.

The common utensils in which milk is handled are not only poorly constructed for the purpose but are usually improperly washed and sterilized. Most cans and pails are made of galvanized iron which is not the best material from which to make such equipment. Their construction, commonly of several pieces of material which are overlapped, soldered and riveted together, needs considerable improvement to facilitate proper cleaning. Likewise, the common methods of washing milk utensils leaves much to be desired. These matters have both been discussed in more detail elsewhere.

Various practices commonly followed in the routine handling of milk contribute to its poor quality, particularly its bacterial content and the quality of the milk as affected by bacterial growth. Milk is frequently transported over long distances in an open pail. This practice is followed in all types of weather, rainy, dusty or otherwise. Such milk is exposed to considerable contamination by the dust and dirt of public roads and city streets. A common practice, to prevent the milk from spilling out of such containers, is to put green leaves, green grass, or dried grass, hay or straw into the milk to keep it from

splashing about. Such materials not only fail to prevent contamination from the air but themselves contribute considerably to the bacterial contamination of the milk. The various means of transporting milk are mostly slow and allow adequate time for bacterial growth to take place sufficiently that spoilage commonly occurs in milk that would otherwise reach the customer in good condition. The high temperature of well water and the general lack of refrigeration makes it impossible to cool milk adequately to prevent bacterial growth. Consequently the bacteria count of milk increases very rapidly. Were it not for the bactericidal property of freshly drawn milk it would be impossible to handle the quantities of milk that are now being handled by the methods employed.

The chemical quality of market milk in India, apart from the effect of bacterial growth, is altered by adulteration to an extent directly proportional to the amount of water added. The extent of adulteration is, unfortunately, appalling. Innumerable diseases are transmitted through water; even deep wells have been known to become contaminated. The water in village tanks, from which a large portion of the supply for use in many rural areas comes, is always highly contaminated with bacteria of nearly every sort, particularly water and soil types. The addition of such water to milk is most certainly a hazard to public health.

Legislation exists in most of the provinces and several of the states regarding the minimum chemical quality permitted for market milk. The first such law was passed by Bombay city in 1899; the first provincial act was that of the United Provinces which was enacted in 1912 (18). Considerable variation is noticed in the presumptive standards for the chemical quality of the milk of both the zebu and the buffalo. So far as information is available on the composition of milk in different parts of India, as indicated in Chapter IV, such wide variations cannot be fully justified. No such laws have yet been enacted to control the bacteriological quality of milk.

The standards prescribed in the various parts of India are given in the following table (18).

STANDARDS FOR FRESH MILK UNDER THE FOOD ADULTERATION ACTS

Province/State	Minimum percentage of milk fat	Minimum percentage of solids-not-fat	Minimum percentage of lactose	Specific gravity at 15·5°C.
COW (ZEBU) MILK—				
North-West Frontier Province and Ajmer-Merwara ..	3·5	8·0	....	....
Punjab, United Provinces, Bihar, Bengal, Assam, Bombay Province, Sind, Baroda city and Hyderabad (Dn.)	3·5	8·5	4·0 (United Provinces). 4·4 (Bengal and Sind).	1·028 to 1·030 in United Provinces and Bengal. Not less than 1·028 in Assam.
Central Provinces, Madras Province*, Mysore* and Cochin* States	3·0	8·5	....	....
BUFFALO MILK—				
Madras Province* Mysore* and Cochin* States ..	4·5	9·0	....	....
North-West Frontier Province, Punjab, United Provinces, Ajmer-Merwara and Delhi Province	5·0	9·0	4·0 (United Provinces).	1·028 to 1·030 in United Provinces.
Central Provinces	5·0	8·5	....	....
Bihar, Bengal, Assam, Bombay Province, Sind, Baroda city and Hyderabad (Dn.).	6·0	9·0	4·4 (Bengal and Sind).	1·028 to 1·03 in Bengal. Not less than 1·028 in Assam.
MIXED MILK—				
North-West Frontier Province, Delhi Province, Ajmer-Merwara and Central Provinces	3·5	-- --	4·0	....
Punjab	3·5	8·6 to 9·0	....	....
Bihar	5·0	9·0	4·0	....
SKIMMED MILK—				
United Provinces, Sind and Bombay Province ..	....	8·7	....	....
Central Provinces	....	8·5	....	....

*In Madras Province, Cochin and Mysore States, cow (Zebu) milk should have a minimum of 0·5 per cent and buffalo milk 0·53 per cent of nitrogen. Both the milks should not have more than 5 parts of sediment per 100,000 parts of milk on 24 hours standing.

Efforts to check compliance with this legislation are meagre. The report quoted above states, 'On the basis of 23,900 samples of milk per annum and 800 lakh maunds of milk estimated to be marketed in India for consumption in urban areas alone, it works out that one sample is collected for every 3,400 maunds of milk......it means that during the course of 68,000 sales one sample is subject to municipal examination.' This must not be taken to imply that since the chances of detection are so few, adulteration may be practised. Each act of adulteration is itself a violation of the moral obligation to society of the one committing the offence both because of the economic deception involved and the danger to public health.

Special Problems

Certain problems in the marketing of milk in India are quite different from those of less tropical countries. The atmospheric temperature prevailing during most of the year in a major part of the country so affects the ground temperature that milk cannot be cooled adequately by the use of tap or well water to retard bacterial growth. The atmospheric temperature, at the same time, encourages bacterial growth in the utensils. This results in greater contamination of the milk than would be true in a colder climate were the same standards of sanitation maintained. Under ordinary conditions milk may deteriorate very quickly with spoilage resulting, consequently every effort must be made to deliver milk to the consumer within the shortest possible time after it is drawn from the cow, unless mechanical refrigeration is employed.

Another problem arises from the conventional methods of handling food products in the home. Only sufficient food for a single meal is usually prepared at a time. This is done because it is not safe, because of the possibilities of contamination, the climatic temperature and the lack of refrigeration facilities, to hold unused food from one meal to the next. In keeping with this practice, the customer will purchase at one time only that milk which can be consumed at one meal and insist that it be delivered to the home just as it is required. Facilities generally make it impossible to hold milk for any length of time in the dairy as well as in the home. This creates two problems in the marketing of milk. Firstly, since most

people take their meals at about the same time, it reduces the period of time during which milk deliveries may be made; secondly, small quantities only may be handled by one salesman and he must deliver to each home more than once daily. This tends to some extent to discourage the use of motors for the delivery of milk, for they are economical only when handling full laods, and encourages the use of cycles. The cost of delivering milk directly to the customer increases as the quantity delivered per delivery man per day diminishes.

Because milk cannot be held for any length of time, due principally to the lack of refrigeration, and since it must be supplied to the consumer only as it is needed, the time at which the cows are to be milked must be set accordingly. The milking time, therefore, is commonly between two and five o'clock in the morning and afternoon so that the milk may reach the customer between five and eight o'clock. Deliveries are commonly made twice daily. Shortages of labour and equipment have been responsible for laws in the United States prohibiting deliveries oftener than each alternate day during the war. This is possible, however, only where the climatic temperature is helpful for at least a part of the year and where dairies and homes are both generally equipped with refrigeration facilities that make it possible to hold milk until it is required.

In order to overcome some of these difficulties in India, particularly with regard to the handling and distribution of milk, attempts have been made to transport milk while hot, at pasteurization temperature or higher. This practice is used to some extent but has not yet been widely adopted. In the hot weather, cans are sometimes covered with a heavy cloth which is kept wet. The evaporation of the water from the cloth delays any effect of the air temperature in increasing that of the milk. Whatever else may be done, more attention must be given to the sanitation of the utensils and equipment in which the milk is handled.

Transportation of Milk

Many different methods are employed for the transportation of milk. Some of these are used rather generally, others only in isolated instances. Among these are the delivery of milk by driving the cow from door to door where she is milked, the

transportation of milk by head load, hand load, cycle, *ekká*, tonga, bullock cart, motor or train.

The extreme difficulty encountered in getting genuine milk has encouraged the continued use of the very ancient practice of driving the cow to the customer. Sufficient milk is then drawn to satisfy the needs of that customer and the cow is driven on to the next. Some people consider this the only way by which they can be certain that the milk they obtain is genuine. The adulteration of milk is practised not only by producers and distributors but also by household servants. Producing the milk in front of the customer at his door is no guarantee, therefore, that it will not be adulterated before it is consumed. It is likewise no guarantee of clean safe milk. The method is such that however conscientious the *gwálá* may be in matters of the sanitary production of milk, it is not possible to produce milk free of contamination. The dust and dirt of most streets, usually swirling about because of the wind, the passage of motor or other vehicles, will contaminate the udder, teats and coat of the cow, the hands and clothes of the *gwálá*, and the milking pail. If a rope is used for leading the animal, it is usually allowed to drag in the street during milking; it is grasped by the milker while leading the cow to the next consumer. If the rope is not used the cow is driven along by repeated patting or slapping with the hands. The calf usually accompanies the cow to stimulate her milk flow. It is commonly guided along with the hands or pushed away from the cow when milking commences. Milking by the wet-hand method is very common. This practice is to be condemned in the srongest terms, apart from the condition of the hands of the milker who drives his cow along from house to house. The thought of drinking water in which someone has washed his hands and the teats of his cow is nauseating, yet considerable quantities of milk used in that manner are consumed with little or no objection. Some people go so far as to argue 'why should I care about quality, I boil my milk before I use it!' The milking pail likewise becomes contaminated as it is carried along. Because it is wet with milk, perhaps containing a little milk not taken by a customer, dust and dirt readily stick to it. Not uncommonly is the pail rinsed out with water available along the streets. This method of milk delivery should be

discouraged on hygienic grounds. It is very questionable whether, as compared to others, it is an economical method. The quantity of milk that may be handled by one man is limited by the production of the cow, and that may only be delivered slowly. Greater production would also result if the cow were milked out quickly and completely at one time rather than intermittently.

Large quantities of milk are transported by head or hand loads. These methods are slow, that is the time required to deliver a unit of milk is considerable. This factor limits the amount of milk one man may handle, depending, to some extent, of course, upon the distance involved. The common use of an open container adds to the unsatisfactory condition of milk transported by either of these means.

The bicycle is used very extensively for transporting milk from the producer to the consumer. Probably a greater portion of the milk that is marketed in India is handled by bicycle than by any other means. The cycle is particularly useful where hard surfaced roads exist and where a market for large quantities of milk is available. Such cycles are loaded with as much as two maunds of milk which may be transported over distances up to 14 to 18 miles in some cases. The containers used in the transportation of milk by cycle are usually closed cans. Open pails are sometimes used, as are also earthenware pots. In any case the containers are ordinarily not properly cleaned and sterilized. In fact, it is commonly noted that the milkman washes his container at a city tap after meeting his customers and before returning to his home. This is expected to be sufficient until after the completion of the next delivery, regardless of the weather and its part in contributing to bacterial growth. Where this means of transport is employed for door to door delivery the can used commonly has a valve from which to draw the milk so the can need not be opened each time. Such valves are rarely constructed so that they may be easily dismantled for cleaning, consequently they are a source of considerable contamination.

Some milk is transported by *ekká* or tonga. These are horse-drawn vehicles in which rather large quantities of milk may be transported. They are used for distances generally not exceeding 15 miles as they are slower, as a rule, than the cycle. Any advantage there may be in their use, as

compared to the cycle, probably lies in the greater load that may be handled. The container commonly used in this case is the closed can.

The bullock cart is not used so often as other vehicles for transporting milk, although it may be used considerably in certain places. Milk is usually handled in quantities much smaller than could be economically handled by this type of conveyance in which loads up to one ton can be carried. The bullock cart is extremely slow, except where light trotting bullocks are used, for which reason it hardly lends itself to use with a perishable product such as milk.

Some milk, probably a very small proportion of the total marketed in India, is transported by motor. This method of transport is employed primarily by large dairies or milk supply unions where they must go considerable distances into the country side to get the quantity necessary to meet their demand. Large quantities of milk can be transported rapidly by this means. Closed containers are always used. The maximum distance over which milk is transported by motor so far is about 20 to 40 miles, but these distances are gradually increasing.

There are instances in which milk is transported by rail. This method usually involves extensive organisation for assembling the milk at the railway station and for receiving it in order that it is always ready at train time, and always immediately removed from the terminus. Large quantities of milk are moved into large cities, such as Delhi, Calcutta, Madras, Lahore and Bombay, by train. Very little if any milk is regularly transported by this means elsewhere. Nowhere are special trains run for the purpose. There are special cars, however, on regular trains running into Calcutta, Madras, Bombay and possibly other cities in which milk, and other produce, is handled.

A recent development in the transport of milk by rail is that of a firm which handles about 50 maunds of milk daily. The milk is toned to 6·2 per cent fat and then cooled to 32°F. until partial freezing takes place. It is then stored under refrigeration until 150 to 175 maunds are accumulated when it is transported to the market in a special insulated railway van. Shipments are made twice weekly. The trip takes about 9 hours for a distance of about 216 miles. The

low temperature is maintained during the journey by the use of ice which is placed about the cans inside the insulated van. The air is then circulated by means of an electric fan. Upon arrival at the destination the milk is transported immediately by insulated motor van to hotels or mills which purchase it on contract. Milk so handled without pasteurization is likely to be consumed without boiling. The public health considerations of this method of supplying milk, therefore, must be given careful attention. Properly supervised from this point of view, this may offer a means of supplying milk to large cities from somewhat remote producing areas.

The keeping quality of milk, which unfortunately is generally poor, limits the length of time milk may be held, transported or otherwise handled between production and consumption. The speed of transport to a large extent, therefore, limits the distance over which it may be moved from the producing area to the market. The faster means of transport, such as the motor van and train, extends the area rather considerably from which a particular market may obtain milk. Until milk is produced under conditions which will increase its keeping quality and until faster means of transportation of the milk are employed, the areas under different milk sheds may not be expected to extend much beyond what they are today. If the production of milk within municipal limits is to discontinue, as it should, the production intensity of the present milk shed areas must either increase or these areas must be extended, probably both.

Marketing of Milk

Many types of marketing organizations exist. These vary so much in their method of organization and operation that it is difficult to classify them. The following, however, may give some idea of the existing organizations and their manner of operation.

Gośále and *Piñjarápol*

The majority of the milk produced in urban areas is produced in *gośále* and *piñjarápol*. This milk is usually sold to individual customers by house to house delivery or to the *halwái*, who may in turn deliver the milk but usually sell it only in their shops.

Small Producer-Distributors

Some milk is marketed to individual customers by village *gwále* who distribute the milk they produce. This method generally involves only a small quantity of milk and a few customers. Such milk is commonly distributed by milking the cow at the door of the customer or by transporting it by head or hand load, sometimes by cycle.

Cycle Vendors or Jobbers

A considerable quantity of milk is marketed by cycle vendors or jobbers. These persons buy milk from village producers, frequently on contract. Delivery of the milk is taken twice daily at the producer's house; it is transported to the city by cycle and sold either by house to house delivery, to the *halwáí* or to tea shops and hostels. These vendors commonly pay the producer a sum of money in advance which may equal the value of the milk purchased over a period of a week or two. Not infrequently, however, do they fail to renew this advance on time. Such milk may be sold on credit or for cash.

Halwáí

The *halwáí* is a maker of milk sweets. He usually maintains a small shop in which he also handles milk and *dahí*. *Halwáí* do not commonly deliver the milk to the consumer, except possibly where large individual orders are involved. The usual practice is to offer the milk and milk products for sale in the shop only. Purchases are usually by cash, although credit is sometimes allowed.

Milk Bazaars

The milk bazaar is an organized wholesale market which may be owned privately or by an association of merchants. It is a market in which quantities of surplus milk may be offered for sale or where it is possible to obtain milk in fairly large quantities when needed. The prices in such a bazaar are fixed partly by supply and demand and partly by the control that is exercised by those managing the bazaar. Dealers may maintain shops there in which they do job separating, or deal in whole milk, skim milk and/or cream, all of which are bought and sold freely in the bazaar. Certain of the dealers operating in the Ahmedabad Milk Bazaar, Ahmedabad, purchase cream on the

basis of the butter fat percentage. Whole milk is received and separated by the dealer who returns the skim milk to the supplier. Cream is usually sold on the basis of the butter outturn. The skim milk is sold in the bazaar as it is produced. The cost of job separation is about two or three annas a maund. Those utilizing this service sell the cream and skim milk separately in the bazaar. The management of the bazaar takes no responsibility for the collection and payment of accounts of its patrons but charges a small percentage on all transactions made there.

Dairies

There are roughly three types of dairies in India. Those handling rather small quantities of milk of which a portion may or may not be produced by their own herd, those handling rather large quantities of milk, and/or milk products, which may or may not be produced by their own herd, and the co-operative dairies. Of these, the latter is discussed separately in some detail. A rigid classification is impossible for there are many variations in the type of organization and the nature of the business carried on.

Small Private Dairies—The more common dairy is that of the first type. Such organization maintains a shop or milk plant where the milk is received from the producer or from its own herd and from which it is distributed. The milk purchased from other producers may be obtained in the manner used by the cycle vendor, that is delivery is taken at the house of the village producer, the milk being purchased on contract or otherwise with or without payment in advance. It is then transported to the milk plant, usually by cycle, and made available to the customers by house to house delivery and/or sale at the dairy. Some of the milk may be converted into various milk products such as cream, *dahi*, butter and ghee. Cheese and ice cream are rarely made by these smaller dairies. Sales may be by cash or credit; tickets are sometimes used.

One example of a successful small dairy is Singhal's Dairy near Agra, U. P. This dairy is located in a small village about three miles from Agra. The dairy owns no cows. Whatever milk it handles is purchased largely in the village in which the dairy is located. Employees of the dairy go twice daily to the homes of the producers and milk their cows. This reduces

the number of persons handling the milk before it gets to the dairy, thereby reducing the chances of it being adulterated. The milk is then bulked and transported to Agra by tonga where it is issued to delivery men who distribute it by cycle from house to house to regular customers who pay cash or purchase tickets. A small amount of cream and butter is made and distributed in the same manner. The organization of this dairy is a very good example of dairying as a village industry. It has been operating successfully for over 20 years.

A somewhat different dairy of this same type is the Malwa Creamery, Ujjain, Central India. This dairy likewise owns no cows. Milk is purchased by contract on daily cash payment. Most of the milk is delivered by the producer to the dairy where it is weighed and tested for curd content as a check against adulteration. This test consits of recovering the curd from one *chhatánk* (about two ounces) of milk by coagulating the milk with sour whey, slightly heating it and straining it through a muslin cloth. The curd is weighed. The purity of the milk is expressed in terms of units of weight, equal to one old-style Gwalior pice, of the curd so obtained. Payment for the milk is made strictly on the basis of the results of this test at the rate of Re. 1/- for so many units. The curd is examined to make sure it does not consist partly of added flour which might interfere with the usefulness of the test in detecting adulteration. All business is strictly cash, even the daily purchase of milk.

A portion of the milk so obtained is sold as whole milk, customers coming to the dairy to get it. The remainder is separated and the cream and skim milk sold separately. Some butter and ghee are made, although a good portion of the cream is sold as such. The skim is sold either directly or after being converted into *dahí*. This dairy has created a market for skim milk and skim milk *dahí* by a programme of education in the local schools with the help of the local Medical Officer of Health.

Large Private Dairies—Edward Keventer, Limited, Aligarh, manufactures butter, casein and cheese at Aligarh and operates a number of dairies elsewhere, such as at New Delhi, Simla, Calcutta and other places, where pasteurized milk from a herd of cows, owned by the firm, is sold in bottles by house to

house delivery or in a retail shop. Delivery is made by cycle, wagon and motor. Products manufactured at Aligarh are supplied to branch dairies in the different cities as well as to private dealers elsewhere. A certain amount of business is done directly by railway with private customers not served by one of the many branch dairies owned by the firm or by one of the dealers.

Polson Limited, Bombay, purchase all their milk, for they own no cows. Butter is manufactured in large quantities in their factory at Anand. Milk is purchased for the purpose on the basis of the percentage of butter fat it contains. This is also done by Edward Keventer, Limited, at Aligarh. The butter is distributed by rail and sold in almost every part of the country through authorized dealers. Skim milk is converted into casein which is dried artificially, ground and graded before it is sold.

The Allahabad Agricultural Institute Dairy is a privately owned organization which is similar in most respects to the non-military government dairies. Milk from its own herds of Red Sindhi, Murrah and cross-bred cows is partially converted into ice cream, cheese, *dahí*, cream, butter and ghee. Milk and milk products are sold by cash or tickets to regular customers, largely by house to house delivery by cycle. Some deliveries are made by tonga and some sales are made at the dairy.

Government Dairies—The largest government dairy organization is that operated by the Military Farms Department. Each Military Dairy, as these dairies are often called, owns a large herd of cross-bred and buffalo cows. The milk produced by these animals, sometimes supplemented by purchases outside, is bulked in their milk plant and distributed to military personnel with or without pasteurization. Butter is usually made for sale to the same clientele. Delivery is made by cycle, tonga or motor. Cheese and dried milk is now made in large quantities in one of these dairies.

Examples of other government owned dairies are those associated with educational institutions or experimental stations, such as the Punjab Agricultural College, Lyallpur; and the Indian Dairy Research Institute, Bangalore. Very fine herds of dairy cattle are maintained at some of these places, such as the Sahiwal herds at the Imperial Institute of Agricultural

Research, New Delhi and the Punjab Agricultural College, Lyallpur; the Red Sindhi herd at the Government Cattle Farm, Hosur, Madras and the herds of Red Sindhi zebus and Murrah buffaloes at Bangalore. For the most part such dairies handle only the milk produced in their own herd. This is supplied to hostels, hospitals and private customers by both wholesale and retail sale. Considerable attention is given in dairies of the last two kinds to improving the processes and equipment involved in handling milk and manufacturing milk products.

Co-operative Dairying

Since the passing of the Co-operative Societies Act in 1912 by the Government of India many co-operative dairy organizations have been established. Although some of these have gone into liquidation for one reason or another, the present trend as a whole seems to be toward more co-operation in the field of dairying as in other fields of agricultural and rural endeavour. Most co-operative dairies handle milk as their major commodity with milk products being manufactured as a means by which to dispose of surpluses. There are a few such organizations, however, which are intended to handle primarily one or more milk products.

The co-operative movement has been brought about largely by the assistance and encouragement of the government. In many cases the initiative has come from this source. It is essential that laws be enacted by government to make such organizations possible, but stronger and more successful co-operative societies would be expected to result when the people themselves supply the initiative. Milk producers in general and to a considerable extent distributors and consumers, are not greatly interested in devoting their time and efforts to an organization that belongs largely to others, that is, to a society, rather than to themselves. An interest on the part of all members and employees in the welfare of the society as a whole rather than in themselves is essential to the success of co-operative enterprises. Such organizations may function and consistently show some profits where the management is interested in the salary it receives or the public attention such work brings; but the real objective, that is, the provision of a type or quality of service not available elsewhere, to all

concerned, will not be attained. Reasons for the slow progress made so far by co-operative dairy enterprises have been listed as follows (18): unhealthy competition from unscrupulous and dishonest petty dealers; failure on the part of the consumer to appreciate quality; lack of statutory backing; lack of support from health authorities and others; and inadequate business acumen and lack of experience on the part of the organizing and supervising staff.

Three types of co-operative dairy organizations have been established so far. These are the consumer's co-operatives, the distributor's co-operatives and the producer's co-operatives.

Consumer's Co-operatives

There is a small number of consumer's co-operative dairies in India; the Burnpur Co-operative Dairy, Burnpur, near Asansol is such an organization. This dairy was organized by employees of the Indian Iron and Steel Company living in Burnpur to assure adequate supplies of good quality milk for use in their homes. This society purchased a herd of Hariana cows, rented land from the steel company, built sheds and barns and hired a qualified manager. The managing committee is elected by the stockholders and is responsible for employing the manager and controlling the finances of the society. The manager is responsible to the managing committee for supervising the working of the organization and for all accounts. This dairy has been operating successfully for several years and continues to fulfill its original purpose satisfactorily. Plans are being made to move it to a new site where sufficient land will be available on which to produce the necessary fodder in order to reduce the cost of producing the milk.

The Ahmedabad Co-operative Ghee Supply Society, Ltd. at Ahmedabad was established in January 1943. In this case, private consumers and ghee dealers jointly organized the society whose objective is to supply adequate ghee of good quality to its members. Whole milk, purchased in the rural areas surrounding Ahmedabad, is received at collecting stations, managed by the society, where it is separated. The cream is sent to the processing plant maintained in the city; the skim milk is converted into casein at the collecting station and transported to the plan where it is graded for sale. The cream is churned

without the addition of salt or butter colour. The butter is held for a day or two for ripening and then heated to produce ghee which is supplied to members; any excess over their demands is then sold to others at market rates. Records of the costs involved are carefully kept. The price paid for milk is fixed by the managing committee, but for the most part it is competitive rather than profit-sharing, since the members of the society are consumers of ghee, not milk producers. The price of ghee, however, is determined from time to time on the basis of the cost of production, concession rates being allowed only to members. Any profits accruing are divided between a reserve fund and dividends to the stock-holders who are also customers. The proprietor of the Gujarat Dairy Farm, Ahmedabad, is honorary secretary of the co-operative society. It is in his dairy premises that the ghee is made and sold; he is responsible for the management of the society and the keeping of the records of its operations for which he receives a nominal salary.

Other consumer's co-operatives exist, although they are not so numerous as those organized for the benefit of the producers. The two just discussed illustrate those handling milk and those handling one or more milk products as their principal commodity.

Distributor's Co-operatives

Distributor's co-operatives are uncommon but they are one of the most useful types of dairy co-operatives from the stand-point of the public service they can render. Their objectives are to improve the welfare of the distributors by supplying the customer more promptly and regularly with milk of a better quality, which is less frequently adulterated.

One such co-operative organization was started in 1930 by the Radha Swami Educational Institution Dairy, Dayalbagh, Agra. Members were those who undertook the transportation of milk from the producer to the consumer, that is cycle vendors or distributors. The main objective of this society was to supply a much better quality of milk than was ordinarily available. The milk was to be supplied more promptly and regularly and was to be of the best possible quality and unadulterated. These objectives are in the interests of the distributor, as well as the consumer, for the more regularly and

promptly the milk is supplied and the better the quality of that milk, the greater the demand created for the services of the distributor. To attain these objectives, milk was purchased on the basis of its butter fat percentage and prizes were awarded to the distributors for the largest sales during a year, consideration being given to the quality of milk supplied to the consumer, its butter fat content, solids-not-fat content and freshness at the time of delivery.

A very large part of the milk consumed in urban India is supplied through jobbers or vendors and a considerable proportion of that is supplied in a very poor condition. This condition is partly due to the lack of a proper appreciation, on the part of the consumer, of the value of quality; it is due as well to the unintentional neglect of the distributor in properly caring for the milk or its intentional adulteration by him or the household servant. The objectives of the distributor's co-operative are of the greatest value in the realms of public health and public service; they not only improve the quality of the milk and service provided by the milk distributor but involve a certain amount of education of the consumer in these matters. Such organizations, therefore, must give considerable attention to educating the consumer properly to appreciate quality and to realize that not infrequently the milk is adulterated by the servants employed in the home. Any efforts that might be made in improving the quality of milk available in urban areas could be expected to be most successful if spent in organizing distributors into societies of this type. The assistance of the local health authorities would contribute greatly towards fulfilling the objectives of such co-operatives.

Producer's Co-operatives

Co-operative dairy organizations of this type are more numerous than either of the two just discussed. Societies of this type have been operating for a number of years with certain of them proving quite successful. One of the first such societies established, after the passage of the Co-operative Societies Act in 1912, was the Katra Co-operative Dairy, Ltd., Allahabad, registered in 1913. During 1936-37 it had one primary society of 45 members and was handling an average of about eight maunds of milk daily. One of the largest societies of this type is the Calcutta Co-operative Milk

Union, Ltd., Calcutta which was registered in 1919. In 1936-37 it had 124 primary societies with 8,359 members; an average of about 104 maunds of milk were being handled daily. The Madras Co-operative Milk Supply Union, Ltd., Madras, registered in 1927, handled an average of about 88 maunds of milk daily in 1938-39; it had at that time 14 primary societies with 800 members. One of the latest producer's co-operative dairies to be established is the Lucknow Co-operative Milk Supply Union, Ltd., Lucknow, which was registered in 1938. In 1939 and 1940 it had 40 primary societies with 450 members and handled an average of over 31 maunds of milk daily. At least one other such society has been organized since then, that is the Allahabad Co-operative Milk Supply Union, Ltd., Allahabad.

Details as to the organization and operation of some of these societies may be of interest.

The Katra Co-operative Dairy, Ltd., Allahabad is probably the oldest existing dairy organization registered under the Co-operative Societies Act of 1912. Only shareholders may be members of the dairy; shares cost Rs. 5/- each. Members are required to sell all of their milk to the dairy. One vote is allowed each shareholder regardless of the number of shares he may own, which is unlimited. Members meet annually to elect an executive committee of five of which three are members, one an honorary chairman and one an honorary secretary. The executive committee meets monthly to consider general management policies, the fixing of wages of the employees and the setting of the price at which the milk will be purchased from members and sold to the public. There is one primary society maintaining three centres, of which one is at the dairy, where members milk their cows in the presence of the manager or a *muṉśi*, appointed by the honorary chairman, who measures the milk and puts it into cans which is then sealed. The milk delivery men, employed by the dairy for delivering the milk to the customers, then take the milk to the dairy where the manager remeasures and reseals it before it is delivered to the customers by head load or cycle. At the annual meeting of the members, any profits are distributed between a building fund, a bad debt fund, a reserve fund, charity and a bonus to the members.

This dairy is now handling about 5 maunds of milk daily

which is received from 78 members owning 81 shares. The milk of the zebu is sold separately from that of the buffalo. All employees are paid on a monthly basis; no commissions are allowed.

The Calcutta Co-operative Milk Union, Ltd., Calcutta, was registered in 1919 after two years of operating a number of societies. These societies are scattered between 12 and 48 miles from Calcutta city. Most of the societies are found in villages that are on or near the railway. The cows are milked by paid servants of the union who turn the milk over to a carrier, also a paid servant. The animals are milked at the house of the member, the milk is recorded by the carrier, when he receives it, in a pass book maintained by each producer. This carrier takes the milk to the secretary of the society, also a paid servant of the organization. The secretary makes the necessary record of the quantity of milk and the producers after which the carrier takes the milk on to an assembling centre where it is received by the manager, who is again paid by the Union. Eighteen such assembling centres are in operation. The milk is transported to Calcutta by rail by the manager or the assembly station. From one maund ten seers to two maunds of milk accompany a carrier possessing a third class ticket. The quality of the milk is tested at the village, at the assembling centre and at the dairy at Calcutta. Fat tests are made periodically as a further check upon the quality.

At the dairy the milk is pasteurized and distributed through delivery men paid on a monthly basis.

The price at which the milk is purchased from producer members is determined twice a year. Milk is delivered principally in bottles. Payment is made either in cash or deposits are made monthly in advance against which daily supplies are delivered. Concession rates or wholesale prices are made to hospitals, but not to private customers.

The Lucknow Co-operative Milk Supply Union, Ltd., Lucknow, was registered in 1938 after a period of 16 months during which the Co-operative Department of the United Provinces organized the village milk supply on a co-operative basis. The 40 primary societies under the union are located between 8 and 16 miles from Lucknow. A certain number of selected buffaloes were supplied in 1939 to members at cost,

payment being realized by deductions from the amount the or milk they supplied.

All animals are milked by their owners at a central place in the presence of the *pañchāyat* elected for the purpose. Care is taken that the milkers' hands and the animals are washed before each milking to assure good quality milk. A paid servant of the union in each village records the milk supplied by each member. Lactometers are used to test samples of milk as an assurance of proper quality milk being supplied. Further tests of other types are carried out occasionally.

Paid carriers transport the milk from the villages to the assembling centres, usually distances of four or five miles, by head loads or bicycles. At the assembling centres the milk is heated to about 160°F. It is then transported hot by motor van or tonga to the union plant in Lucknow. The milk usually arrives after about 2 hours at a temperature of 125°F.; it is immediately cooled to less than 45°F. It is then delivered to the customers by cycles.

Milk is sold either in bottles or bulk. Quantities of cream, butter, ghee and skim milk are also sold at the union plant.

The management of the union is directed by a Board of Directors of 11 members of which one is the Deputy Commissioner of Lucknow, five are representatives of milk societies, one is a representative of individual shareholders, two are nominated by the Registrar of Co-operative Societies and two are co-opted by Board of Directors.

The Telankheri Dairy Co-operative Society, Nagpur, was registered in 1922. There are now 26 members, owning 90 shares of stock, who keep about 450 milking zebus and buffaloes at a central place. About 1,000 acres of grazing land and a few buildings are rented by the society from the Government. The animals are fed and cared for at this place by their owners who are members of the society. Grain and fodder grass are made available by the society at slightly more than cost. Grazing cost is eight annas a month for each animal over one year of age. Milking is done twice daily under the supervision of employees of the Government Farm nearby, for which the society pays a very small honorarium. The milk produced by the members is sold to and marketed by the Byramji Dairy which is the selling section of the society.

Membership is limited to shareholders who may own one or

more shares at Rs. 100/- each. Only members are permitted to use the facilities offered by the producing section of the society, although some milk is purchased from non-members and handled by the selling section. A managing committee of eight members consists of one nominee of the Director of Veterinary Services, Central Provinces, and seven elected by the members at an annual general meeting; the committee elects its own chairman. The president of the society is elected by the members from among their seven electees to the managing committee. The secretary, appointed by the managing committee, may or may not be a member of the society. Members may appoint any one as treasurer, although they have usually appointed the Superintendent of the local Government Farm. A joint secretary is appointed by the managing committee from their membership. A manager is appointed, and his salary is fixed, by the managing committee, with the approval of the members of the society and the Director of Veterinary Services. The liability of the members is at present unlimited, although it is proposed that the society become a limited concern in the near future.

In addition to the milk produced by the members, the Byramji Dairy purchases milk from the Government Farm and from two small co-operative dairy societies at the same basic price paid to its own members. Profits are shared by the members only, however, as follows: 25 per cent is retained as reserve, a dividend of up to six per cent is paid on all stock, the remainder is given as a rebate to members in proportion to the milk they supplied. Income is realized from milk products, manure, grass and feed grains, in addition to the sale of milk which amounted to an average of 2485 pounds a day during 1944. Loans may be made to members for purchasing cattle.

CHAPTER XV

GOATS AND OTHER ANIMALS AS MILK PRODUCERS

Large quantities of milk produced by animals other than the zebus or buffaloes are used for human food purposes in India. The milk of the goat and of the sheep is of particular importance in this respect, although that of the camel and of the ass is used in small quantities. The 1940 census shows 620 lakhs of goats, 451·1 lakhs of sheep, 906 lakhs of camels and 16·8 lakhs of asses in the country (18). The milk from only a small proportion of these animals, however, is used as a food for man. It is estimated that only about 16 per cent of the goats are hand milked; no estimates are available for the others.

It is stated in Chapter II that the milk of these animals is not widely used, although it is consumed in certain localities. Goat milk is used more widely than that of the sheep. The use of sheep milk is confined largely to the hill tracts where sheep are found in large numbers. Camel milk is used only in the North-West Frontier Province and in Sind; the use of ass milk is largely confined to the Kathiawar States.

Goat

Approximately 251·2 lakh maunds of goat milk is produced each year in India of which ·59 lakh maunds are consumed by the kids. Approximately 192·2 lakh maunds of this milk, therefore, are available for human consumption. This represents about 3·1 per cent of the total milk used for this purpose, the remainder being almost exclusively the milk of the zebu and buffalo cows.

Goats are found in grater numbers in the United Provinces, Rajputana, Hyderabad and the Punjab than elsewhere. Those in the Punjab, North-West Frontier Province and Bihar, however, are the best milk producers. The average production per year is estimated to be 440 pounds in the Punjab, 365 pounds in the North-West Frontier Province and 340 pounds

in Bihar: the average for all of India, 161·8 pounds (18). The largest amount of goat milk, that is 37·43 lakh maunds, is produced in the Punjab. The United Provinces follow with 24·60 lakh maunds per year (18). The Punjab produces almost 26 per cent of the goat milk produced in India; United Provinces, 13 per cent.

The principal breeds of milk goats are the Jumnapari, Bar-Bari, Beetle, Surti and Cutch. The production of these different breeds is not well known, for the number of records available is rather limited. Records at Etah for 1941 indicated an average of 489 pounds in a lactation of 150 days for the Jumnapari breed and 359 pounds in a lactation of about 150 days for the Bar-Bari breed. These averages represent only about 40 records, however, for each breed. Individual yields are reported to be as high as 700 to 1000 pounds at Etah in the United Provinces and at Hissar in the Punjab.

The chemical composition of the milk of the goat has been given in Chapter IV. The protein content of goat milk is slightly greater than that of the zebu, whereas the casein content is less and the albumen and globulin content somewhat higher. The factors that are listed in Chapter IV as influencing the composition of milk affect that of goat milk as well. The extent of the effect in each case, however, is not so well known for goat milk as for that of western or taurus cows. Adequate information on these points, in fact, is lacking for the Indian cow of both the zebu and the buffalo species.

Goat milk seems to have two characteristics which make it valuable for infants or for older people with slightly weakened digestive systems. The average size of the fat globule in goat milk is less than that in zebu or buffalo milk. The significance of small fat globules in nutrition is discussed in Chapter IV. The fact may be repeated, however, that the smaller the globules the easier the fat is digested because the surface area with which the digestive fluids come into contact will become greater per unit volume of fat as the size of the globule diminishes. This increases the rate of digestion.

Another valuable character of goat milk is its soft curd character or low curd tension. Turner and Garrison (103) studied the curd tension of milk from the goat and the taurus cow. They report that the curd tension of goat milk, using the Cobb instrument and the Hill method, averaged 55 grams,

varying from 30 to 100 grams, whereas that of taurus herd milk averaged 70 grams. Besley (7), however, observed in experiments on infants and rats that little difference in the nutritive value of goat milk and taurus milk resulted from differences in curd tension or fat globule size; that an exclusive diet of either type of milk produced anaemia unless iron and copper were supplied; and that human infants gained weight in direct proportion of the quantity of nutrients consumed in either form.

A simple formula has been suggested by Peterson and Turner (80) for estimating the food energy value of goat milk. It is not known whether this formula is applicable to goat milk in India, but it is of interest and may find some use until its applicability here is finally determined. The formula is: $Y=39{\cdot}618+9{\cdot}564X$, where Y is the energy value of 100 millilitres of goat milk and X is the fat percentage of that milk, provided it is between 3·5 and 5·5 per cent.

Goat milk is not of general importance in the milk markets of India. The reasons for this are, firstly, the production of goat milk constitutes such a small porportion of India's total and, secondly, most of such milk is utilized by the family of the producer. Very little goat milk is bought or sold in any form. Some, which may or may not be mixed with the milk of the sheep, is converted into ghee, particularly in Gujerat, Baroda and the Punjab.

As the manufacture of cheese develops there is no doubt that some fine quality cheese will be made from goat milk as well as from that of the sheep. Some of the finest varieties of European cheese are made from these types of milk. Experimental batches of a fresh cream cheese or soft cheese have been made at the Mission Poultry Farm, Etah, United Provinces. Very little if any such cheese is made elsewhere.

Sheep

Sheep are generally kept for their supply of wool and meat. Few if any sheep are kept in India primarily for milk production. Where attention has been given to the systematic breeding of sheep it has been for purposes of increasing their utility fundamentally as wool producers. There are, however, two breeds of sheep which produce comparatively large quantities of milk, namely, the Lohi and the Damani. It is reported that individuals of either of these breeds are capable

of producing as much as 10 or 12 pounds of milk a day, an amount more than sufficient for the proper nourishment of their lambs.

The composition of milk of the sheep has been indicated in Chapter IV. There seem to be no characteristics of sheep milk which give it special value as a food for human purposes. Most sheep produce such small quantities that it is considered unwise to remove much of the milk by hand. Where sheep milk is consumed, therefore, its use is confined mainly to the supply of the needs of the owner and his family. Very little if any milk from the sheep is marketed.

Some ghee is made from this milk in Gujerat, Baroda and the Punjab. As was suggested in reference to the possibilities in goat milk for cheese making purposes, as the manufacture of this milk product develops it is possible also that the milk of the sheep may be used. The genuine French Roquefort cheese is made from sheep milk and is considered an excellent cheese. The production of sheep milk must be greatly increased in India, however, before any appreciable amount will be available for ghee or cheese making.

Camel

It is estimated that the camel produces between five and eight pounds of milk per day, yielding a total of about 1500 pounds per lactation (18). Another report (56) indicates that the camel may give up to 2500 litres or 5500 pounds of milk in a lactation, giving as much as 5 to 12, sometimes 15, litres or between 11 and 33 pounds a day. The fat percentage usually varies between 4·5 to 5·6 per cent. A kind of cheese known as *Tilsit* is made from camel milk, according to Kheraskov (56). There is no estimate of the number of camels used for the production of milk in India, for it is not a common practice even where camels are found. It is questionable whether any camel milk is marketed in India, except possibly in scattered instances involving very small quantities.

The composition of the milk of the camel is given elsewhere. Little is known about the milk of this species of animal with regard to any special qualities it may have for use as a human food. It is not possible to say, therefore, how it compares qualitatively with the milk of other species. Its importance

quantitatively is practically insignificant in India and may be found to be of reasonable significance in only very small areas elsewhere.

Ass

The milk of the ass is used to a limited extent for food purposes. The production of milk by the ass in Kathiawar and Cutch is estimated at 230 pounds per lactation (18). The milk is reported to be used principally for feeding infants under medical advice.

APPENDICES

APPENDIX I

Calf Feeding Schedule

Every time a zebu or buffalo is put into a calving stall, a few days prior to parturition, the question of whether the calf, if a male, should be retained is to be taken up with the head or acting head of the department. No calf should be allowed to suck its dam more than three days; unless absolutely necessary for milking, all calves should be kept away from their dams entirely. Immediately after birth the calf's naval cord should be cut and disinfected. The calf should be allowed to suck only after the cow's udder is thoroughly cleaned and the fore milk is taken out. Calves are to be fed at 4·00 A.M., 1·00 P.M., and 8·00 P.M.

Age	No. of feedings each day	Whole milk per feeding	Skim milk per feeding	Grain mix per day	Grass per day	Silage per day	Remarks
		lbs.	lbs.	lbs.	lbs.	lbs.	
1st week	3	2½*	—	—	—	—	Milk is fed warm from the cows.
2nd-3rd week.	3	2½	—	¼	1	—	Salt is fed *ad libitum.*
4th week	3	1½(2½)**	1(0)	½	2	—	
5th ,,	3	2(3)	1(0)	½	3	—	Calves are watched for scours.

Age	No. of feedings each day	Whole milk per feeding	Skim milk per feeding	Grain mix per day	Grass per day	Silage per day	Remarks
		lbs.	lbs.	lbs.	lbs.	lbs.	
6th week	3	2(3)	1(0)	1	4	—	All changes in feeding are made gradually.
7th-8th ,,	3	1½(2½) (1½)	2(2)	2	5	—	
9th ,,	3	—	3½	2	6	—	Milk is separated immediately while warm.
10th-12th ,,	3	—	4	2	8	2	Grain is divided into 2 feeds, morning and evening.
4th-5th month ,,	3	—	4	3	10	3	
6th month	3	—	5	4	12	4	Feed all the roughages the calves will eat.

*Colostrum only is fed the first few days.
**Figures in brackets indicate the amounts for weak calves.

Grain mixture:—

Wheat bran	3 maunds
Linseed cake	1 maund
Ground barley	2 maunds
Ground *jwār*	2 maunds
Ground maize	2 maunds
Mineral mixture	3 per cent

APPENDIX II

Standard Nutrient Requirements for Growing Dairy Cattle

Figures, except nutritive ratio, are pounds required daily.

Body weight lbs.	Dry matter	Digestible crude protein		Total digestible nutrients		Nutritive ratio
		minimum	good	minimum	good	
250	5·9-6·9	0·61	0·71	4·1	4·8	5·7-6·2
300	7·2-8·0	0·67	0·78	4·9	5·5	6·3-6·8
400	9·0-10·0	0·80	0·90	6·1	6·6	6·5-7·0
500	10·6-11·8	0·87	0·98	6·9	7·7	6·9-7·4
600	12·0-13·6	0·94	1·06	7·7	8·7	7·2-7·7
700	13·4-15·5	1·00	1·13	8·4	9·7	7·4-7·9
800	14·8-17·4	1·06	1·20	9·1	10·7	7·6-8·1
900	16·1-19·2	1·11	1·27	9·8	11·7	7·8-8·3
1000	17·5-21·0	1·16	1·33	10·4	12·6	8·0-8·4

APPENDIX III

Standard Nutrient Requirements for the Maintenance of Dairy Cows

Figures are in Pounds.

Body weight	Dry matter	Digestible crude protein		Total digestible nutrients	
		minimum	good	minimum	good
600		0·395	0·416	4·50	5·10
650	16*	0·413	0·446	4·80	5·40
700		0·440	0·476	5·13	5·81
750		0·467	0·506	5·45	6·18
800	19*	0·494	0·536	5·77	6·53
850		0·521	0·564	6·08	6·88
900	20*	0·547	0·593	6·38	7·23
950		0·574	0·621	6·69	7·58
1000	22*	0·600	0·650	7·00	7·93

Figures marked with an asterisk are from Bulletin 48 of The Ministry of Agriculture and Fisheries.

Morrison (73) recommends:—"The amount of dry matter to be fed daily per 1000 lbs. live weight to dairy cows may range from 15·0 lbs. or even less for dry cows, to 30·0 lbs. for cows yielding 2·0 lbs. of butter fat per head daily. Cows producing 1·0 lb. of fat per head daily should receive about 21·0 to 25·0 lbs. of dry matter daily per 1,000 lbs. live weight." He also states "Dairy cows in milk will eat about 2 lbs. of good-quality dry roughage daily per 100 lbs. live weight. Silage may be substituted for dry roughage at the rate of 3 lbs. of silage for 1 lb. of dry roughage. A common rule is to feed 1 lb. of hay and 3 lbs. of silage daily per 100 lbs. of live weight."

APPENDIX IV

Standard Nutrient Requirements for Milk Production

Figures are in Pounds.

Amount of milk daily	Milk containing 4·5% fat				Milk containing 5·0% fat			
	Digestible crude protein		Total digestible nutrients		Digestible crude protein		Total digestible nutrients	
	minimum	good	minimum	good	minimum	good	minimum	good
5·0	0·22	0·26	1·65	1·74	0·23	0·28	1·76	1·86
10·0	0·44	0·52	3·30	3·49	0·46	0·56	3·53	3·73
15·0	0·66	0·78	4·95	5·24	0·69	0·84	5·30	5·60
20·0	0·88	1·04	6·60	6·98	0·92	1·12	7·06	7·46
25·0	1·10	1·30	8·25	8·72	1·15	1·40	8·82	9·32
30·0	1·32	1·56	9·90	10·47	1·38	1·68	10·59	11·19
35·0	1·54	1·82	11·55	12·22	1·61	1·96	12·36	13·16
40·0	1·76	2·08	13·20	13·96	1·84	2·24	14·12	14·92
45·0	1·98	2·34	14·85	15·70	2·07	2·52	15·88	16·78
50·0	2·20	2·60	16·50	17·45	2·30	2·80	17·65	18·65
	Milk containing 5·5% fat				Milk containing 6·0% fat			
5·0	0·24	0·30	1·88	1·98	0·26	0·31	2·00	2·11
10·0	0·49	0·59	3·76	3·97	0·52	0·62	3·99	4·22
15·0	0·74	0·88	5·64	5·96	0·78	0·93	5·98	6·33
20·0	0·98	1·18	7·52	7·94	1·04	1·24	7·98	8·44
25·0	1·22	1·38	9·40	9·92	1·30	1·55	9·98	10·55
30·0	1·47	1·77	11·28	11·91	1·56	1·86	11·97	12·66
35·0	1·72	2·06	14·96	13·90	1·82	2·17	14·96	14·77
40·0	1·96	2·36	15·04	15·88	2·08	2·48	15·96	16·88
45·0	2·20	2·66	16·92	17·86	2·34	2·79	17·96	18·99
50·0	2·45	2·95	18·80	19·85	2·60	3·10	19·95	21·10

APPENDIX IV (Cont.)

Standard Nutrient Requirement for Milk Production

Figures are in Pounds.

Amount of milk daily	Milk containing 6·5% fat: Digestible crude protein		Milk containing 6·5% fat: Total digestible nutrients		Milk containing 7·0% fat: Digestible crude protein		Milk containing 7·0% fat: Total digestible nutrients	
	minimum	good	minimum	good	minimum	good	minimum	good
5·0	0·27	0·34	2·11	2·33	0·28	0·34	2·22	2·35
10·0	0·54	0·65	4·22	4·66	0·57	0·68	4·45	4·70
15·0	0·87	1·00	6·33	6·99	0·86	1·02	6·68	7·05
20·0	1·08	1·30	8·44	9·32	1·14	1·36	8·90	9·40
25·0	1·35	1·62	10·55	11·65	1·42	1·70	11·12	11·75
30·0	1·62	1·95	12·66	13·98	1·71	2·04	13·35	14·10
35·0	1·89	2·34	14·77	16·31	2·00	2·38	15·58	16·45
40·0	2·16	2·60	16·88	18·64	2·28	2·72	17·80	18·80
45·0	2·43	3·02	18·99	20·97	2·56	3·06	20·02	21·15
50·0	2·90	3·35	21·10	23·30	2·85	3·40	22·25	23·50

APPENDIX V

Classification of Concentrate and Roughage Feeds with the Approximate Digestible Crude Protein and Total Digestible Nutrient Contents of Each Class

Figures are in per cent.

Type of feed		Digestible crude protein (D.C.P.)	Total digestible nutrients (T.D.N.)
Oil cakes	..	25 to 35	60 to 75
Legume grains	..	11 to 15	70 to 80
Cereal grains	..	5 to 8	65 to 75
Wheat bran	..	10	65
Arhar husk	..	4 to 5	60 to 65
Straws, stovers or dried grasses	..	1 to 2	35 to 50
Legume hays	..	8 to 10	50 to 60
Green grasses with 30% D.M.*	..	1 to 2	15 to 20

*Note:—D. M. refers to the dry matter content. Grains and dry fodder have a dry matter content of between 90 and 98 per cent; silage between 35 and 40 per cent; and succulent fodder between 15 and 40 per cent.

The amount of D. M. required daily for dairy animals is as follows: 1·8 to 2, possibly 3, pounds for each 100 pounds of body weight, depending upon whether the animal is dry or milking. Those milking should receive more than those dry. Cows of average body weight which are producing about 20 pounds of milk should receive between 21 and 25 pounds of D. M. daily.

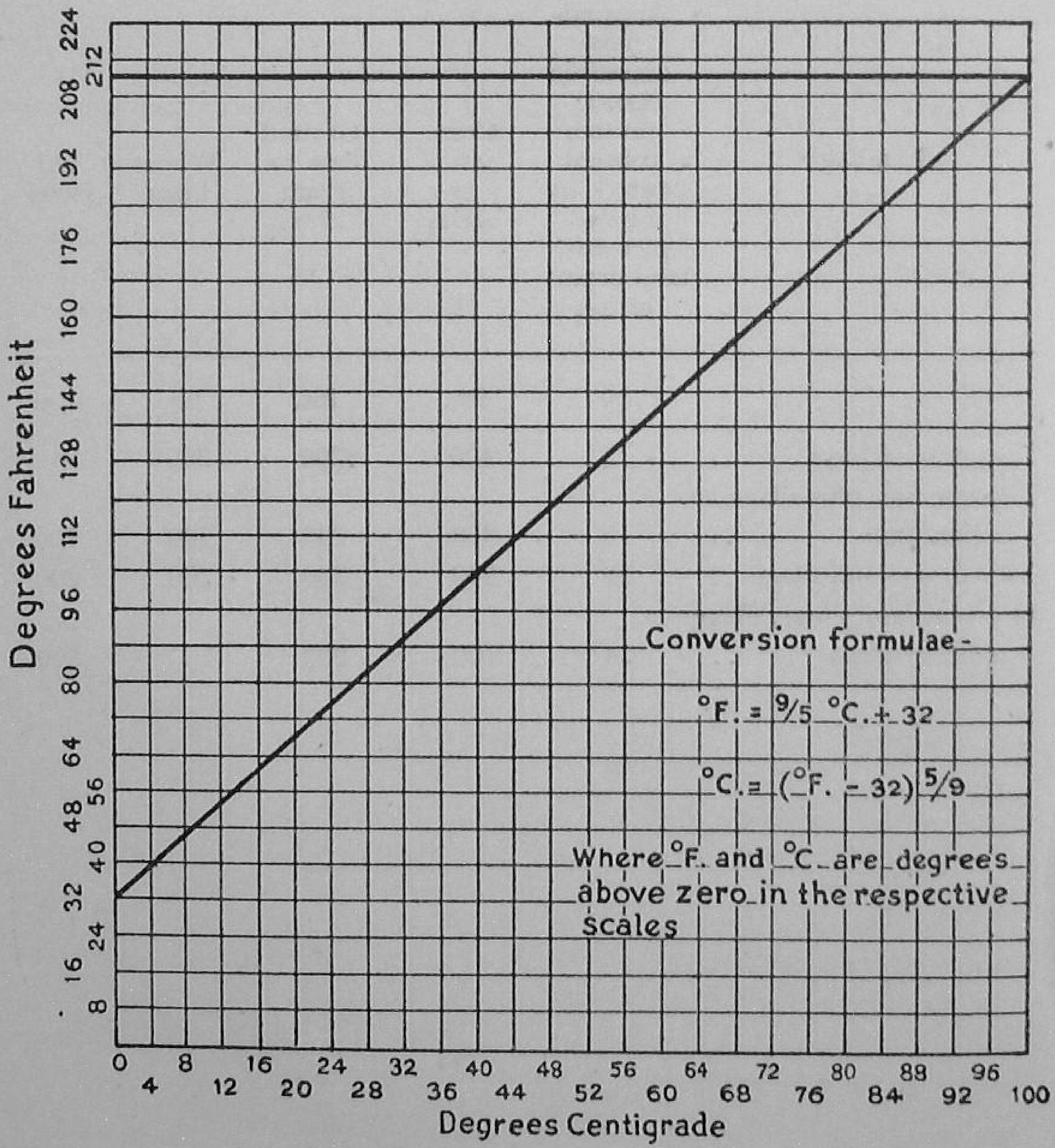
APPENDIX VI

Classification of Roughage Feeds with the Digestible Crude Protein Content Desired in a Supplementary Grain Ration and Suggested Formulae for Grain Rations for Each Class

Roughages	Approximate digestible crude protein content desired in the supplementary grain ration	Corn, *jawār* or barley	Ground oats or gram *chūnī*	Wheat bran	Oil cakes
	%	lbs.	lbs.	lbs.	lbs.
Leguminous hays ..	12	400	200	200	—
Legume hay plus silage or mixed hays ..	16	300	200	200	100
Mixed hays and silage ..	20	200	200	200	200
Grass hay and silage, silage alone or straw ..	24	100	200	200	300

APPENDIX VII

RELATIONSHIP BETWEEN THE FAHRENHEIT AND CENTIGRADE TEMPERATURE SCALES



APPENDIX VIII

Dairy Arithmetic

Short-cuts in Common Dairy Calculations

Innumerable short-cuts in ordinary calculations may be used to reduce the time or paper required or to simplify them. Some of those which have been found of use in creamery calculations are given here.

1. When dividing one number by another number like ten (10), one hundred (100), one thousand (1,000), ten thousand (10,000), one hundred thousand (100,000), one million (1,000,000), etc., set the decimal place to the left in the dividend that number of places which is equal to the number of digits in the divisor, less one. When multiplying by such figures, set the decimal place to the right in the multiplicand that number of places which is equal to the number of digits in the multiplier, less one.

For example: To divide any number by 10, set the decimal point over one place to the left; to multiply, set it over one place to the right.

$100 \div 10 = 10 \cdot 0$ $\qquad$ $9432 \cdot 83 \div 10 = 943 \cdot 283$

$1011 \cdot 1 \times 10 = 10111 \cdot 0$ $\qquad$ $8216 \cdot 235 \times 10 = 82162 \cdot 35$

To divide by one hundred, set the decimal point over two places to the left; to multiply, set it over two places to the right.

$10 \cdot 0 \div 100 = 0 \cdot 10$ $\qquad$ $9432 \cdot 83 \div 100 = 94 \cdot 3283$

$1011 \cdot 1 \times 100 = 101110 \cdot 0$ $\qquad$ $8216 \cdot 235 \times 100 = 821623 \cdot 5$

2. Practice in the use of short-cut number 1 will make this one easier, otherwise it will appear a somewhat round-about procedure rather than a simplified one.

a. A number which is to be divided by 5 (or 50) may be multiplied by 2 and then divided by 10 (or 100).

For example: $32 \div 5 = 6 \cdot 4$ $\qquad$ or $\quad 75 \div 50 = 1 \cdot 5$

also $32 \div 2 = 64$ $\qquad$ also $\quad 75 \times 2 = 150$

$64 \div 10 = 6 \cdot 4$ $\qquad$ $150 \div 100 = 1 \cdot 5$

b. A number which is to be divided by 2·5 (or 25) may be multiplied by 4 and then divided by 10 (or 100).

For example: 28÷2·5=11·20	or 213÷25=8·520
also 28×4=112·0	also 213×4=852·0
112.0÷10=11·20	852·0÷100=8·520

c. A number which is to be multiplied by 25 (or 50) may be divided by 4 (or 2) and multiplied by 100.

For example: 121×25=3025·0	or 3·9×50=195·0
also 121÷4=30·250	also 3·9÷2=1·950
30·25×100=3025·0	1·95×100=195·0

Practice in the use of these examples will reveal innumerable other possibilities, such as dividing a number by 3 instead of multiplying it by 33·3 per cent; dividing by 8 instead of multiplying by 12·5 per cent, and others.

3. A number to be multiplied by 18 (or 99) may be first multiplied by 20 (or 100) from which 2 (or 1) times the number is subtracted.

For example: 36×18=648·0	or 327×99=32,373·0
also 36×20=720·0	also 327×100=32,700·0
720·0−72=648·0	32700·0−327=32,373·0

4. The multiplier times the multiplicand equals the multiplicand times the multiplier. For this reason it frequently facilitates multiplication to use as the multiplier that one of the two numbers involved having the fewer digits.

For example:

35×9838161=344370635

```
35                       9839161
×9839161       also      ×    35
---------               ---------
       35               49195805
      210               29517483
      35                ---------
     315                344370635
    105
   280
  315
---------
344370635
```

The second method has the advantage of occupying less space, of being less confusing, and of taking less time to complete.

One may, according to the convenience afforded, multiply the two figures in an inverted manner, or in a reverse fashion.

For example:

```
 ×35          or      9839161
  9839161             ×    35
 ---------            ---------
  49195805            29517483
 29517483              49195805
 ---------            ---------
 344370635            344370635
```

Relationship of Per Cent, Decimals and Fractions

Per cent may be defined as parts by, in or to one hundred. The term is an abbreviated form of the Latin *per centum* meaning each hundred. Five pounds, therefore, are 5 per cent of one hundred pounds; not 5 per cent of ten pounds, of 37 pounds nor 99·5 pounds, but of *one hundred* pounds.

Consequently the figure representing the percentage of a particular constituent in milk, for example, also represents the pounds of that constituent in 100 pounds of milk, the grams of that constituent in 100 grams of milk, or the tons of that constituent in 100 tons of milk. The unit employed may be a unit of weight, of measure or of any object with which one is dealing.

Per cent is written either in words or by use of the symbol %, hence 14 parts in one hundred may be written as per cent in two ways, *viz.*, 14 % or 14 per cent. The same quantity may also be expressed, not as per cent however, in other ways, *viz.*, 0·14 or 14/100, which shows at a glance the relationship between per cent, decimals and fractions.

To convert a percentage figure into a decimal it is necessary only to place the decimal point two places to the left in the figure and drop the designation per cent or %.

For example:

	62·8 %	of 194 = 0·628 × 194
or	62·8 %	of 194 = 62·8 ÷ 100 × 194
also:	62·8 %	of 194 = 62·8 × 194 ÷ 100
but:	62·8 %	does *not* equal 0·628%

Decimals:—

For the help of those who may not easily understand the use

of decimals, which are for so many persons much easier and simpler than fractions, rules determining the position of the decimal point, when dividing or multiplying decimals, may be stated briefly.

1. When multiplying decimals, the number of digits to the right of the decimal point in the product shall equal the number of digits to the right of the decimal point in the multiplicand plus those in the multiplier.

For example:

$$38 \cdot 125 \times 1 \cdot 17 = 44 \cdot 60625$$

There are three digits, *viz.*, 1, 2 and 5, to the right of the decimal point in the multiplicand and two digits, *viz.*, 1 and 7, to the right of the decimal point in the multiplier; consequently the number of digits to the right of the decimal point in the product shall be $3+2$ or 5.

2. When dividing decimals, the position of the decimal point in the quotient can best be determined by the following steps:

a. Move the decimal point to the right in the dividend as many places as there are digits to the right of the decimal point in the divisor.

For example:

$$38 \cdot 125 \div 1 \cdot 17 = 32 \cdot 585470$$

first: $1 \cdot 17$ has two digits to the right of the decimal point, hence the decimal point in $38 \cdot 125$ shall be moved two places to the right to give $3812 \cdot 5$

b. Then eliminate the decimal point in the divisor.

second: $1 \cdot 17$ becomes 117

c. Divide as in ordinary long division.

third:

```
117)3812·5(325
    351
    ----
     302
     234
     ---
      685
      585
      ---
      100
```

```
or:        117)3812·500000(32585470
               351
               ----
                302
                234
                ----
                 685
                 585
                 ----
                 1000
                  936
                 ----
                   640
                   585
                   ----
                    550
                    468
                    ----
                     820
                     819
                     ----
                      10
```

d. Mark off as many places in the quotient as there are in the dividend.

fourth: 32·5

or: 32·585470

Determination of the Salt Content of the Moisture Fraction of Butter

Assuming the moisture content of butter is 15·1 per cent and the salt content 2·5 per cent, calculate the per cent of salt in the moisture.

NOTE:—Almost all the bacteria involved in the deterioration of butter grow in the water fraction, attacking materials found in solution or possibly materials immediately surrounding a tiny water droplet imbedded in the body of the butter. Salt is not soluble in fat, but is soluble in water; hence the addition of salt to butter greatly increases the salt concentration of the water fraction in which the bacteria are found. The salt and osmotic pressure tolerance of bacteria varies with the species, but is rather low for many of the organisms commonly found in butter. The preservative action of salt can, to some extent, be indicated in this calculation.

a. Make a table to show the composition of the butter and its fat-free fraction. Fill in the blanks where the figures are known.

	butter	fat-free fraction
water	15·1	81·62*
fat	81·5	—
salt	2·5	13·51*
milk solids-not-fat	0·9	4·68*

*figures calculated as shown below.

b. Use 100 pounds of the butter to facilitate calculations, for the percentage content of each constituent is then equal to pounds in the butter used.

c. Subtract the fat per cent in the butter from 100 to give the pounds of fat-free fraction.

$$100 - 81{\cdot}5 = 18{\cdot}5$$

d. Calculate the percentage of 18·5 pounds that is represented by 15·1 pounds of water, 2·5 pounds of salt and 0·9 pounds of milk solids-not-fat.

$$15{\cdot}1 \div 18{\cdot}5 \times 100 = 81{\cdot}62$$
$$2{\cdot}5 \div 18{\cdot}5 \times 100 = 13{\cdot}51$$
$$0{\cdot}9 \div 18{\cdot}5 \times 100 = 4{\cdot}86$$

Enter these figures in the appropriate spaces in the table under a.

The Composition of Home Made Ice Cream

Using whole milk from the zebu, of the composition given in Chapter IV, calculate the composition of a home-made ice cream mix made from this milk and having 13·00 per cent fat and 14·00 per cent added sugar.

a. Make a table to show the composition of the milk used, its fat-free fraction and of the ice cream made from it. Fill in the blanks where the figures are known.

	whole milk	fat-free fraction	ice cream
water	86·56	91·04*	86·46*
fat	4·92	—	13·00
protein ..	3·21	3·38*	2·47*
lactose ..	4·58	4·82*	3·52*
ash	0·75	0·79*	0·58*
sugar (added) ..	—	—	14·00
	100·02	100·03	100·03

*figures calculated as shown below.

b. Use 100 pounds of the whole milk to facilitate calculations, for the percentage of each constituent is then equal to pounds in the amount of milk used.

c. Subtract the fat per cent in the whole milk from 100 to give the quantity of fat-free fraction.

$$100 - 4 \cdot 92 = 95 \cdot 08$$

d. Calculate the percentage of 95·08 pounds that is represented by 86·56 pounds of water; by 3·21 pounds of protein; by 4·58 pounds of lactose; and by 0·75 pounds of ash.

$$86 \cdot 56 \div 95 \cdot 08 \times 100 = 91 \cdot 04$$
$$3 \cdot 21 \div 95 \cdot 08 \times 100 = 3 \cdot 38$$
$$4 \cdot 58 \div 95 \cdot 08 \times 100 = 4 \cdot 82$$
$$0 \cdot 25 \div 95 \cdot 08 \times 100 = 0 \cdot 79$$

Enter these figures in the appropriate spaces in the table under a.

e. Subtract from 100 the fat plus the added sugar (13·00+14·00 or 27·00) in the ice cream to get the pounds of fat-free milk fraction in the ice cream.

$$100 - 27 \cdot 00 = 73 \cdot 00$$

f. Calculate the pounds of water, protein, lactose and ash in 73·00 pounds of fat-free milk fraction contained in 100 pounds of ice cream mix, using the percentages calculated in d.

$$73 \cdot 00 \times 91 \cdot 04\% = 73 \cdot 00 \times 0 \cdot 9104 = 86 \cdot 46$$
$$73 \cdot 00 \times 3 \cdot 38\% = 73 \cdot 00 \times 0 \cdot 0338 = 2 \cdot 47$$
$$73 \cdot 00 \times 4 \cdot 82\% = 73 \cdot 00 \times 0 \cdot 0482 = 3 \cdot 52$$
$$73 \cdot 00 \times 0 \cdot 79\% = 73 \cdot 00 \times 0 \cdot 0079 = 0 \cdot 58$$

g. Enter the figures obtained in f in their respective spaces in the table under a, for they indicate pounds in one hundred pounds of mix, consequently percentage.

Note:—The figures obtained in the fat-free fraction of whole milk incidentally represent practically the composition of skim or separated milk. The presence of 0·01 to 0·03 per cent of fat (see Chapters IV and VIII) will make no appreciable difference in the composition of skim milk from the fat-free fraction of whole milk. It will be noticed that as the fat is removed, the percentage of each remaining constituent increases. This represents another reason for the high food value, although not necessarily a high calorific value, of skim milk.

The Calorific Value of Milk

Determine the calorific value, firstly, of 100 gms. and, secondly,

of one pound of buffalo milk of the following composition: fat 7·16%, protein 3·77%, lactose 4·81% and ash 0·76%.

1. a. $100 \text{ gms.} \times 7.16\% = 100 \text{ gms.} \times \frac{7.16}{100}$

$= 100 \text{ gms.} \times 0.0716$

b. hence: 7·16% of 100 gms. = 7·16 gms. of fat
3·77% of 100 gms. = 3·77 gms. of protein
4·81% of 100 gms. = 4·81 gms. of lactose

c. We know that: 1 gm. of fat gives 9 Cal. of heat energy
1 gm. of protein gives 4 Cal. of heat energy
1 gm. of lactose gives 4 Cal. of heat energy

d. Therefore:

7·16 gms.	× 9 Cal.	=	64·44 Cal.
3·77 ,,	× 4 Cal.	=	15·08 Cal.
4·81 ,,	× 4 Cal.	=	19·24 Cal.
			98·76 Cal.

e. 100 gms. of the milk provides 98·76 Cal. of heat energy.

2. a. Same as 1.a.
b. Same as 1.b.
c. Same as 1.c.
d. One pound contains 453 gms. or 4·53 units of 100 gms. each.
e.

7·16 gms.	× 9 Cal.	× 4·53	=	291·9
3·77 ,,	× 4 Cal.	× 4·53	=	68·3
4·81 ,,	× 4 Cal.	× 4·53	=	87·2
				447·4

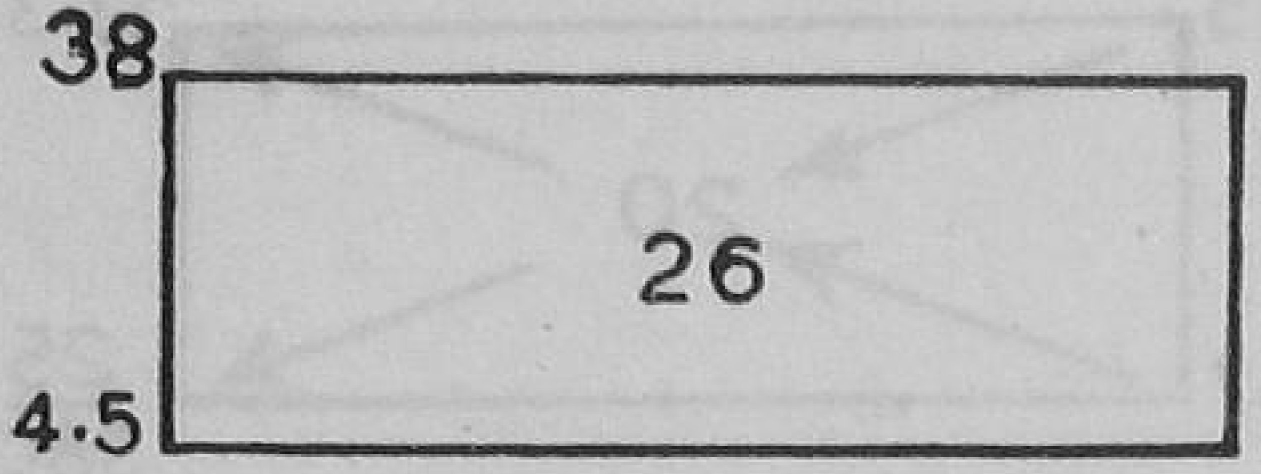
One pound or 453 gms. of the milk provides 447·4 Cal. of heat energy.
Also 98·76 Cal. × 4·53 = 447·4 Cal.

Standardizing or Toning

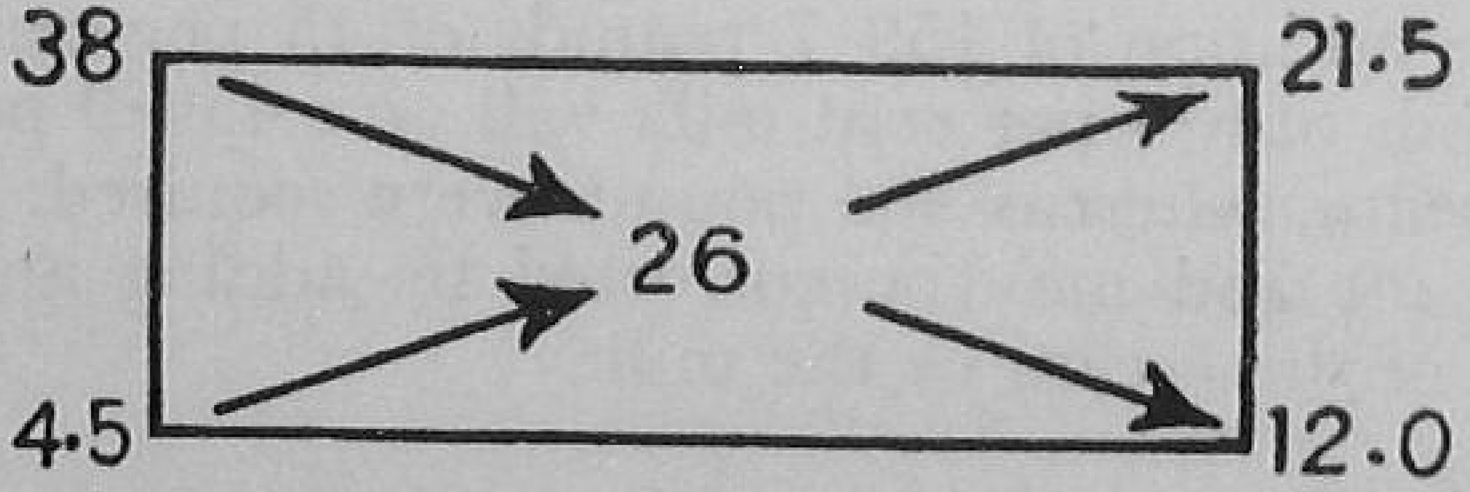
A simple method for calculating the quantities of high and low fat content materials required to give a required quantity of an intermediate fat content is known as the Pearson Square method. Under certain conditions the same method may also be used for standardizing the solids-not-fat content.

1. Calculate the parts of 38 per cent cream and the parts of 4·5 per cent whole milk which must be used to give a mixture containing 26 per cent fat.

a. Draw a rough rectangle and set the fat percentage of the two materials to be used at the left-hand corners and set the desired fat percentage in the centre, as follows:



b. Now subtract diagonally across the rectangle and set the result down at the right-hand corner opposite the subtraction. Subtract the smaller figure from the larger whatever their position. For example, 26—4·5=21·5 which goes in the upper right-hand corner, as follows:

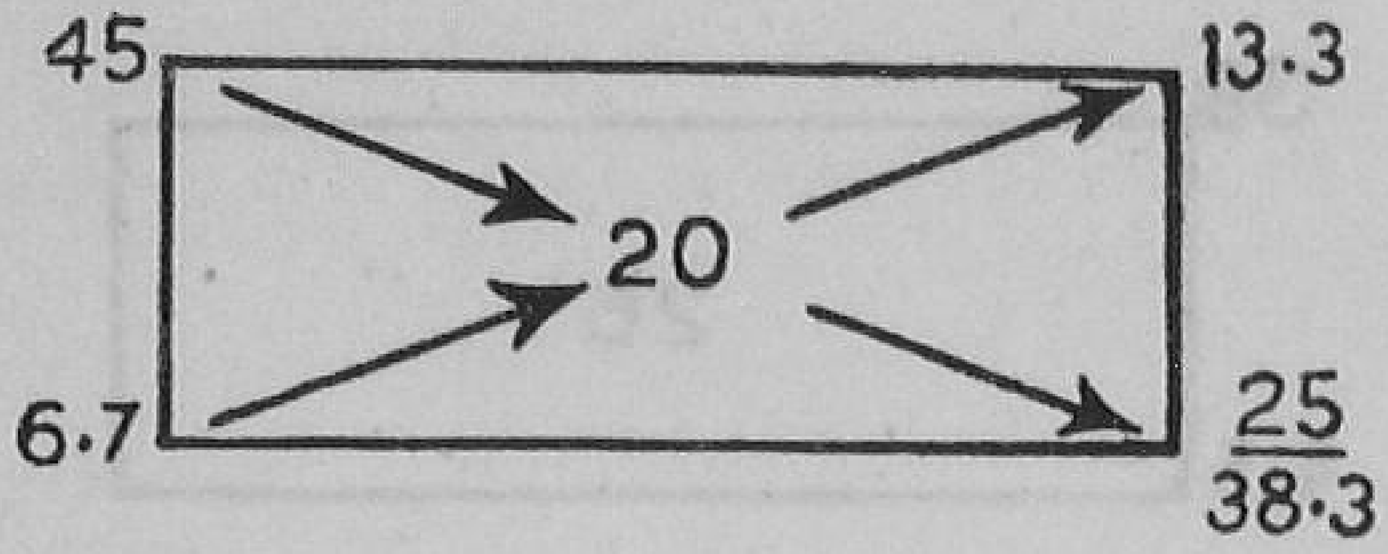


c. The figure 21·5 now represents the parts of 38 per cent cream to use and 12·0 represents the parts of 4·5 per cent milk to use. We now have the proportion in which to mix the two materials to get a mixture of 26 per cent butter fat.

d. The accuracy of this method of calculation may easily be checked. If 21·5 pounds of 38 per cent cream are mixed with 12·0 pounds of 4·5 per cent milk, the mixture will weigh 33·5 pounds. The amount of fat contained in the cream is 21·5×0·38 or 8·17 pounds and the amount of fat in the milk is 12·0×0·045 pounds or 0·54 pounds; the total fat being 8·71 pounds. The amount of fat in 33·5 pounds of material containing 26 per cent fat is 33·5×0·26 or 8·71 pounds, which is the amount obtained by use of the Pearson Square.

2. Calculate the quantities of 45 per cent cream and 6·7 per cent milk required to give 460 pounds of 20 per cent cream.

a. Draw the rectangle and proceed as in number 1.



b. Now divide 460 pounds by 38·3 and multiply by both 13·3 and 25 separately.

The result is as follows:—

$$\frac{460}{38\cdot 3} = 12\cdot 01$$

13·3 × 12·01 = 159·7 pounds of 45 per cent cream
25 × 12·01 = 300·2 pounds of 6·7 per cent milk

c. The addition of 159·7 pounds of 45 per cent cream to 300·2 pounds of 6·7 per cent milk will give 459·9 pounds of 20 per cent cream, whereas 460 pounds were required. The error is insignificant and may be corrected by adding an additional 0·1 pound of the cream or the milk.

Overrun in Butter

The difference between the pounds of butter fat churned, or purchased, and the pounds of butter made, or sold, gives the overrun in butter. The two methods of calculating such overrun differ in that the first is calculated to include only the churning losses or those losses which may occur between the putting of cream into the churn and the removal of the butter from the churn; the second invloves all processing and handling losses which may occur between the purchase of the butter fat and the sale of the butter. Overrun is usually expressed as percentage of the fat churned, or purchased. Churning losses may be expected to involve up to 0·50 per cent of butter fat in the butter milk, although usually somewhat less if the churning process is carefully controlled. Greater losses of fat take place during churning than during any other process during the handling of the butter fat in the butter factory.

Losses of fat occur in the separated milk; in the butter milk; as a result of errors in weighing; as a result of milk, cream or butter adhering to the equipment in which it is handled; and as a result of accidental spilling.

1. Calculate the overrun in percentage of the butter fat purchased if 420 pounds of butter fat were purchased and 503 pounds of butter were sold.

$$\frac{503 - 420}{420} \times 100 = 19{\cdot}76 \text{ per cent overrun.}$$

2. Calculate the percentage of overrun in 71 pounds of butter made from 120 pounds of cream containing 48·0 per cent of butter fat.

$$120 \times 0{\cdot}48 = 57{\cdot}6 \text{ pounds of fat churned;}$$

$$\frac{71 - 57{\cdot}6}{57{\cdot}6} \times 100 = 23{\cdot}26 \text{ per cent overrun.}$$

Overrun in Ice Cream

During the freezing of ice cream there is an increase in volume as a result of the incorporation of air into the body of the product and, although to a much less extent, as a result of the slight increase in volume of the water contained in the product as a result of freezing (see Chapter XI).

The formula to be used in calculating the overrun in ice cream is as follows:

$$\frac{\text{Volume of finished ice cream—volume of original mix}}{\text{Volume of original mix}} \times 100$$

1. Calculate the overrun in a batch of 8 gallons of ice cream which was made by using 4·5 gallons of ice cream mix.

$$\frac{8 - 4{\cdot}5}{4{\cdot}5} \times 100 = 77{\cdot}7 \text{ per cent overrun.}$$

APPENDIX IX

Tables of Length, Capacity, Mass and Area

METRIC SYSTEM OF LENGTH

1 micron	μ	0·001	millimeter
1 millimeter	mm.	0·001	meter
1 centimeter	cm.	0·01	meter
		0·394	inches
1 decimeter	dm.	0·1	meter
		3·937	inches
1 meter	m.	39·37	inches
		3·28	feet
		1·094	yards
		10	decimeters
1 dekameter	dkm.	10·934	yards
		10	meters
1 hectometer	hm.	109·36	yards
		100	meters
1 kilometer	km.	1000	meters
		0·621	mile

METRIC SYSTEM OF CAPACITY

1 milliliter	ml.	0·001	liter
		0·161	cubic inch
1 centiliter	cl.	0·01	liter
		0·07	gill
1 deciliter	dl.	0·1	liter
		0·176	pint
1 liter	l.	1·759	pints
		0·22	gallon
		1000·027	cubic centimeters
1 dekaliter	dkl.	2·2	gallons
		10	liters
1 hectoliter	hl.	100	liters
1 kiloliter	kl.	1000	liters

METRIC SYSTEM OF MASS

1 milligram	mg.	0·001	gram
1 centigram	cg.	0·01	gram
		0·154	grain
1 decigram	dg.	1·543	grains
1 gram (The weight of one ml. of pure water at maximum density (4°C) in a vacuum.)	g.	15·432	grains
		0·564	drams av.
		0·035	ounce av.
1 dekagram	dkg.	5·644	drams av.
1 hectogram	hg.	3·527	ounces av.
1 kilogram	kg.	2·205	pounds av.

ENGLISH SYSTEM OF LENGTH

1 inch	in.	2·540	centimeters
1 foot	ft.	12	inches
		0·305	meter
1 yard	yd.	3	feet
		0·914	meter
1 furlong	fur.	220	yards
		660	feet
		201·168	meters
1 mile	mi.	5280	feet
		1760	yards
		1·609	kilometers

ENGLISH SYSTEM OF AREA

1 square inch	sq. in.	6·452	square centimeters
1 square foot	sq. ft.	144	square inches
		0·093	square meter
1 square yard	sq. yd.	9	square feet
		0·836	square meter
1 acre	A	43,560	square feet
		4,840	square yards
		2·590	square kilometers
		4,046·873	square meters

ENGLISH SYSTEM OF FLUID MEASURE AND CAPACITY

1 minim	min.	0·059	milliliters
1 drachm	fl. dr.	60	minims
		3·551	milliliters
1 ounce	fl. oz.	8	drachms
		28·413	milliliters
		1·805	cubic inches
1 gill	gl.	0·25	pint
		1·42	deciliters
1 pint	pt.	4	gills
		0·568	liters
1 quart	qt.	2	pints
		1·136	liters
1 gallon	gal.	4	quarts
		8	pints
		277·3	cubic inches
		0·160	cubic feet
		4·546	liters
		160	fluid ounces
		10	pounds of water at 15°C.
		1·201	American gallons

ENGLISH SYSTEM OF MASS (AVOIRDUPOIS)

1 grain	gr.	0·065	gram
1 dram	dr. av.	1·772	grams
1 ounce	oz. av.	28·35	grams
		437·5	grains
1 pound	lb. av.	453·592	grams
		7000	grains
		16	ounces
1 stone	st.	14	pounds
		6·35	kilograms
1 hundredweight	cwt.	112	pounds
		8	stone
		50·802	kilograms
1 ton	T.	2240	pounds
		160	stones
		20	hundredweights
		27·222	maunds

INDIAN SYSTEM OF MASS

1 tola	ta.	180	grains
		11·664	grams
1 *chhaṭāṉk*	chk.	5·0	tola
		58·32	grams
1 seer	sr.	80	tolas
		16	*chhaṭāṉk*
		2·057	pounds
		0·933	kilograms
1 maund	md.	40	seers
		82·286	pounds av.
		37·327	kilograms

BIBLIOGRAPHY

1. Aggarwala, A. C. and Ahmed, S. D. (1940). A Laboratory Manual of Milk Inspection. Published by Capt. A. C. Aggarwala, Punjab Veterinary College, Lahore.
2. Annantakrishnan, C. P. (1941). Studies in Ass's Milk Composition. *Journal of Dairy Research* 12, 119.
3. Asghar Ali Shah (1936). Composition of Colostrum from Montgomery Cows. *Indian Journal of Veterinary Science and Animal Husbandry* 6, 234.
4. Associates of L. A. Rogers (1935). Fundamentals of Dairy Science. 2nd. ed. Reinhold Publishing Corporation, New York, U. S. A.
5. Association of Official Agricultural Chemists (1940). Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. 5th ed. Association of Official Agricultural Chemists, Washington, D. C., U. S. A.
6. A World Record Cow. *Veterinary Record* 51, (16), 513, 1939. Reference taken from Aggarwala, A. C. and Ahmed, S. D. (1940). A Laboratory Manual of Milk Inspection. (See reference number 1.)
7. Besley, A. K. (1940). Recent Investigations of Goats' Milk. *American Journal of Public Health* 30, 182. Abstract in *Dairy Science Abstracts* 2, (2), 162. 1941.
8. Bowen, J. T. (1925). Dairy Engineering. John Wiley and Sons, Inc., New York, U. S. A.
9. British Standards Institute (1936). British Standard Apparatus and Methods for Determining the Percentage of Fat in Milk and Milk Products by the Gerber Method. Part 2. Methods. *Specification No.* 696. British Standards Institute, London.
10. British Standards Institute (1937). British Standard Specification for Density Hydrometers for Use in Milk. *Specification No.* 734. British Standards Institute, London.

11. British Standards Institute (1938). British Standard Methods for the Chemical Analysis of Butter. *Specification No.* 769. British Standards Institute, London.
12. Brunner Manufacturing Co. (1942). Refrigeration Service Manual. Brunner Manufacturing Co., Utica, New York, U. S. A.
13. Butter, Ghee and Fat Licensing Rules, 1943, of the United Provinces Prevention of Adulteration Act (1930). *Government Gazette*, December 25, 1943. Superintendent, Printing and Stationery, United Provinces, Allahabad.
14. Cary, C. A. (1939). Blood Constituents. Food and Life: Yearbook of Agriculture. United States Department of Agriculture, Washington, D. C., U. S. A.
15. Central Agricultural Marketing Department (Government of India) (1938). Standard Methods of Analysis for Testing and Grading Ghee. Office of the Agricultural Marketing Adviser to the Government of India, Delhi.
16. Central Agricultural Marketing Department (Government of India) (1940). Provisional Instructions for the Grading and Marketing of Creamery Butter. Agricultural Marketing Adviser to the Government of India, Delhi.
17. Central Agricultural Marketing Department (Government of India) (1943). Report on the Marketing of Hides in India and Burma. *AMA* 41. Manager of Publications, Delhi.
18. Central Agricultural Marketing Department (Government of India) (1943). Report of the Marketing of Milk in India and Burma, 2nd. ed. *AMA* 22.2. Manager of Publications, Delhi.
19. Chalmers, C. H. (1935). Bacteria in Relation to the Milk Supply. Edward Arnold and Co., London.
20. Cole, D. F. (1931). Beginning Accounting. The University Publishing Co., New York, U. S. A.
21. Davies, W. L. (1939). The Chemistry of Milk. 2nd. ed. Chapman and Hall, Ltd., London.
22. Davies, W. L. (1940). Indian Indigenous Milk Products. Thacker, Spink and Co., Ltd., Calcutta.
23. Davis, J. G. (1939). The Resazurin-Rennet Test for the Commercial Control of Milk Supplies. *Dairy Industry* 4, 421. Abstract in *Dairy Science Abstracts* 2, (1), 62, 1940.

24. Davis, J. L. (1944). Britain's Milk Industry. *Dairy News Letter* 25, (3), 4. Dominion Department of Agriculture, Ottawa, Canada.
25. Deming, H. G. (1925). General Chemistry. 2nd. ed. John Wiley and Sons, New York, U. S. A.
26. Department of Commercial Intelligence and Statistics (Government of India) (1942). Statistical Abstract for British India. *DGCIS* 1.8. Manager of Publications, Delhi.
27. Department of Commercial Intelligence and Statistics (Government of India) (1943). India Livestock Statistics, 1940. *DGCIS* 32.5. Manager of Publications, Delhi.
28. Dey, Mrs. I. R. Indian Cookery and Confectionery. Naba Gouranga Press, Calcutta.
29. Doan, C. G. and Matheson, K. J. (1932). Varieties of Cheese: Descriptions and Analyses. United States Department of Agriculture *Bulletin* 608. Government Printing Office, Washington, D. C., U. S. A.
30. Eckles, C. H., Anthony, E. L. and Palmer, L. S. (1939). Dairy Cattle and Milk Production. 3rd. ed. The Macmillan Company, New York, U. S. A.
31. Eckles, C. H., Combs, W. B. and Macy, H. (1943). Milk and Milk Products. McGraw Hill Book Co., Inc., New York, U. S. A.
32. Elsdon, G. D. and Walker, G. H. (1942). Richmond's Dairy Chemistry. 4th. ed. Charles Griffin and Co., Ltd., London.
33. Espe, D. L. (1938). Secretion of Milk. Collegiate Press, Inc., Ames, Iowa, U. S. A.
34. Farrall, A. W. (1942). Dairy Engineering. John Wiley and Sons, New York, U. S. A.
35. Fieldhouse, A. and Fieldhouse, E. E. The Student's Complete Commercial Bookkeeping. 53rd. ed. Published by Arthur Fieldhouse, Hudderfield, England.
36. Gaines, W. L. (1939). Live Weight and Milk-Energy Yield in the Wisconsin Dairy Cow Competition. *Journal of Dairy Science* 22, (1), 49.
37. Ghare, B. K. (1928). Manual of Dairy Farming for Indian Students. Macmillan and Co., Ltd., Bombay.
38. Gomez, E. T. and Turner, C. W. (1938). Recent Advances in our Knowledge on the Endocrine Control of

Mammary Development. *Journal of Dairy Science* 21, Abstract page 118.

39. Hadert, H. (1938). Casein and its Uses. Translated from 2nd. German ed. by Goldsmith. Chemical Publishing Company of New York, New York, U. S. A.
40. Haldar, Mrs. J. (1943). Bengal Sweets. Industry Publishers, Ltd., Calcutta.
41. Hammer, B. W. (1938). Dairy Bacteriology. 2nd. ed. John Wiley and Sons, New York, U. S. A.
42. Hanley, John. Editor (1936). Progress in Milk Technology. J. Bibby and Sons, Ltd., Liverpool.
43. Harvey, W. C. and Hill, H. (1936). Milk: Production and Control. H. K. Lewis and Co., Ltd., London.
44. Harvey, W. C. and Hill, H. (1937). Milk Products. H. K. Lewis and Co., Ltd., London.
45. Hunziker, O. F. (1926). Condensed Milk and Milk Powder. 4th. ed. Published by the Author, La Grange, Illinois, U. S. A.
46. Hunziker, O. F. (1927). The Butter Industry. 2nd. ed. Published by the Author, La Grange, Illinois, U. S. A.
47. Hunziker, O. F. (1940). The Butter Industry. 3rd. ed. Published by the Author, La Grange, Illinois, U. S. A.
48. Jones, D. B. (1939). Protein Requirement of Man. Food and Life: Yearbook of Agriculture. United States Department of Agriculture, Washington, D. C., U. S. A.
49. Joshi, D. K., Joshi, N. R. and Warner, J. N. (1944). The Cost of Producing Milk and Butter Fat. *The Allahabad Farmer* 18, (1 and 2), 37.
50. Joshi, N. R. (1940). Private Communication.
51. Kartha, K. P. R. (1934). A Note on the Comparative Economic Efficiency of the Indian Cow, the Half-bred Cow and the Buffalo as Producers of Milk and Butter Fat. *Agriculture and Livestock in India* 4, (6), 605.
52. Kartha, K. P. R. (1938). Milk Records of Cattle in Approved Dairy Farms in India. Imperial Council of Agricultural Research, *Miscellaneous Bulletin* 18. *ICAR* 8.18. Manager of Publications, Delhi.
53. Kartha, K. P. R. (1939). Report on a Village Enquiry regarding Cattle and the Production and Consumption of Milk in Seven Breeding Tracts of India. Imperial Coun-

cil of Agricultural Research, *Miscellaneous Bulletin* 22. *ICAR* 8.22. Manager of Publications, Delhi.

54. Kartha, K. P. R. (1941). Milk Records of Cattle in Approved Dairy Farms in India. Part I. Cows. Imperial Council of Agricultural Research, *Miscellaneous Bulletin* 36, *ICAR* 8.36. Part II. Buffaloes. Imperial Council of Agricultural Research, *Miscellaneous Bulletin* 37. *ICAR* 8.37. Manager of Publications, Delhi.
55. Kelley, E. and Clement, C. E. (1931). Market Milk. John Wiley and Sons, New York, U. S. A.
56. Kheraskov, S. (1939). The Manufacture of Cheese from Camels' Milk. *Molochno-Maslodel naya Prom.* 6, (9), 14. Abstract in *Dairy Science Abstracts*, 3, (1), 1, 1940.
57. Kothawalla, Z. R. (1928). Breeds of Indian Cattle. IV. The Kankrej Breed (Dual Purpose). *Journal of the Central Bureau of Animal Husbandry and Dairying in India*, 2, 88.
58. Kothawalla, Z. R. and Kartha, K. P. R. (1939). Studies in the Production of Milk Fat by Hariana and Tharparker Cows in Relation to Factors such as Season, Advanced Lactation, Plane of Production, etc. *Agriculture and Livestock in India* 9, 251.
59. Kothawalla, Z. R. and Khubchandani, P. G. (1940). *Withania Coagulans* as a Vegetable Rennet. *Indian Journal of Veterinary Science and Animal Husbandry* 10, (3), 284.
60. Kothawalla, Z. R. and Verma, H. C. (1942). Studies in the Manufacture of Surati Cheese. *Indian Journal of Veterinary Science and Animal Husbandry* 12, (4), 297.
61. Leather, J. W. and Dobbs, A. C. (1914). The Yield and Composition of the Milk of the Montgomery Herd at Pusa and Errors in Milk Tests. *Memoirs of the Department of Agriculture in India. Chemical Series* 3, 147.
62. Ling, E. A. (1934). A Text Book of Dairy Chemistry. Chapman and Hall, Ltd., London.
63. Macgregor, R. (1941). The Domestic Buffalo. *The Veterinary Record* 53, 31.
64. Meggitt, A. A. and Mann, H. H. (1911). The Composition of the Milk of Some Breeds of Indian Cows and Buffaloes and its Variation. Part I. The Milk of Some Breeds of Indian Cows. *Memoirs of the Department of Agriculture in India. Chemical Series* 2, 1.

65. Meggitt, A. A. and Mann, H. H. (1912). The Composition of the Milk of Some Breeds of Indian Cows and Buffaloes and its Variation. Part II. The Milk of Some Breeds of Indian Buffaloes. *Memoirs of the Department of Agriculture in India. Chemical Series* 2, 195.
66. Milk Recording News. *Indian Farming* 4, (1), 51. 1943.
67. Milk Recording News. *Indian Farming* 5, (4), 192. 1944.
68. Milk Recording News. *Indian Farming* 5, (6) 286. 1944.
69. Milk Recording Not a New System. *Dairy News Letter* 25, (8), 6. 1944. Dominion Department of Agriculture, Ottawa, Canada.
70. Ministry of Agriculture and Fisheries. National Milk Testing and Advisory Scheme. The Standard Routine Test (Provisional Technique). *Form No. CIS 8/T.P.Y.* Abstract in *Dairy Science Abstracts* 4, (4), 185. 1943.
71. Ministry of Agriculture and Fisheries. National Milk Testing and Advisory Scheme. The Ten Minute Resazurin Test (Provisional Technique). *Form No. CISO/T.P.Y.* Abstract in *Dairy Science Abstracts* 4, (4), 186. 1943.
72. Misra, S. R. (1942). Farm Cost Accounts in the Agricultural Institute, Allahabad. *The Allahabad Farmer* 16, (2 and 3), 65.
73. Morrison, F. B. (1937). Feeds and Feeding. 20th. ed. Morrison Publishing Co., Ithaca, New York, U. S. A.
74. Mortensen, M. (1938). Management of Dairy Plants. Rev. ed. The Macmillan Co., New York, U. S. A.
75. Newmark, J. H. (1941). Some Experiments with Papaya in Milk. *Milk Dealer* 30, (10), 40. Abstract in *Dairy Science Abstracts* 3, (4), 258. 1942.
76. Olver, A. (1938). A Brief Survey of Some of the Important Breeds of Cattle in India. Imperial Council of Agricultural Research, *Miscellaneous Bulletin* 17. Manager of Publications, Delhi.
77. Olver, A. and Vaidyanathan, M. (1934). Assessment of the Annual Contribution of Livestock in India to Indian Economy. Proceedings of the First Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry, Page 268. *ICAR* 2.1. Manager of Publications, Delhi.
78. Perriello, R. C. (1944). A Grastroenteritis Outbreak from Food. *Journal of Milk Technology* 7, 68.

79. Perry, E. J. (1939). Among the Danish Farmers. The Interstate. Danville, Illinois, U. S. A.

80. Peterson, V. E. and Turner, C. W. (1939). The Energy Content of Goat Milk. *Journal of Nutrition* 17, 293.

81. Public Health Service Milk Ordinance and Code: 1935, Public Health *Bulletin* 220. United States Treasury Department, Public Health Service, Washington, D.C., U. S. A.

82. Ramji Narain and Atam Singh (1942). Studies on Vegetable Rennet. *Indian Journal of Veterinary Science and Animal Husbandry* 12, (3), 224.

83. Reasons for Keeping Milk Records. *Queensland Agricultural Journal* of 1st. January, 1944. Taken from the *Dairy News Letter* 25, (4), 4. 1944. Dominion Department of Agriculture, Ottawa, Canada.

84. Sammis, J. L. (1942). Cheese Making. 10th. ed. The Cheese Maker Book Co., Madison, Wisconsin, U. S. A.

85. Sen, K. C. (1938). The Nutritive Values of Indian Cattle Foods and the Feeding of Animals. Imperial Council of Agricultural Research, *Miscellaneous Bulletin* 25. Manager of Publications, Delhi.

86. Shaw, J. C. and Peterson, W. E. (1940). The Fat Metabolism of the Mammary Gland of the Cow. *Journal of Dairy Science* 23, 538.

87. Sinha, S. N. (1931). Tweed's Cow-Keeping in India. 5th. ed. Thacker, Spink and Co., Ltd., Calcutta.

88. Sivasubramanian, V. and Dover, C. W. (1938). A Comparative Study of the Colostrum of the Dairy Cow and the Dairy Buffalo. *Indian Journal of Veterinary Science and Animal Husbandry* 8, 29.

89. Smith, W. (1925). Breeds of Indian Cattle. I. The Scindi Breed. *The Agricultural Journal of India* 20. 349.

90. Smith, W. (1928). Breeds of Indian Cattle. III. The Murra Buffalo. *Journal Central Bureau for Animal Husbandry and Dairying in India* 1, 153.

91. Smith, W. and Littlewood, R. W. (1926). Breeds of Indian Cattle. II. The Ongole or Nellore Breed. *The Agricultural Journal of India* 21, 253.

92. Sommer, H. H. (1932). The Theory and Practice of Ice Cream Making. Published by the Author, Madison, Wisconsin, U. S. A.

93. Sommer, H. H. (1938). Market Milk and Related Products. Published by the Author, Madison, Wisconsin, U. S. A.

94. Square Milk Bottles Used in the U. S. A. *Dairy Record* for July 19, 1944. Reference taken from *Dairy News Letter* 25, (8), 7.1944. Dominion Department of Agriculture, Ottawa, Canada.

95. Stirling, I. D. and Blackwood I. H. (1933). The Nutritive Properties of Milk in Relation to Pasteurization. *Bulletin* 5. Hannah Dairy Research Institute, Kirkhill, Ayreshire, Scotland.

96. Sutermeister, E. and Browne, F. L. (1939). Casein and its Industrial Applications. 2nd. ed. Reinhold Publishing Corporation, New York, U. S. A.

97. The Composition of Milk. *Miscellaneous Bulletin* 61. Indian Council of Agricultural Research, New Delhi.

98. The 7,500 Lb. Buffalo Club of India. *Indian Farming* 5, (1), 40. 1944.

99. The 10,000 Lb. Milk Club of India. *Indian Farming* 3, (10), 556. 1942.

100. The 10,000 Lb. Milk Club of India. *Indian Farming* 3, (12), 657. 1942.

101. Turner, C. W. (1935). The Secretion of Milk and the Milking Process. Missouri Agricultural Experiment Station, *Bulletin* 346. University of Missouri, Columbia, Missouri, U. S. A.

102. Turner, C. W. (1936). Factors Affecting the Composition of Milk. Missouri Agricultural Experiment Station, *Bulletin* 365. University of Missouri, Columbia, Missouri, U. S. A.

103. Turner, C. W. and Garrison, E. R. (1940). The Vitamin C Content and Curd Tension of Goats' Milk. Report of the Missouri Agricultural Experiment Station 1936-37, *Bulletin* 413. Abstract in *Dairy Science Abstracts* 2, (2), 164. 1941.

104. U. S. A. Record Milk Output. *Dairy Record* of the 3rd of March, 1944. Reference taken from *Dairy News Letter* 24, (3), 5. 1943. Dominion Department of Agriculture, Ottawa, Canada.

105. Van Es, L. (1932). The Principles of Animal Hygiene and Preventive Veterinary Medicine. John Wiley and Sons, New York, U. S. A.

106. Van Slyke, L. L. and Price, W. V. (1936). Cheese. Rev. ed. Orange Judd Publishing Co., Inc., New York, U. S. A.

107. Vitamin C in Milk. *Monthly Bulletin of the Bangalore Dairy Cattle Society* 3, 50. 1944.

108. Ware, F. (1942). A Further Survey of Some Important Breeds of Cattle and Buffaloes in India. Imperial Council of Agricultural Research, *Miscellaneous Bulletin* 54. Manager of Publications, Delhi.

109. Warner, J. N. (1942). Report of the Department of Animal Husbandry and Dairying, 1941-42. Allahabad Agricultural Institute. *The Allahabad Farmer* 16, (1), 40.

110. Warner, J. N. and Joshi, N. R. (1943). The Economics of Ghee Production in the Village from Buffalo Milk. *The Allahabad Farmer* 17, (1), 1.

111. Williamson, Major G. (1945). Private Communication.

112. World's Milk Record. *Dairy News Letter*. Reference taken from *Indian Farming* 4, (3), 160. 1943.

113. Wright, N. C. (1937). Report on the Development of the Cattle and Dairy Industries of India. *ICAR* 18. Manager of Publications, Delhi.

114. Yapp, W. W. and Nevins, W. B. (1941). Dairy Cattle Selection, Feeding and Management. 3rd. ed. Chapman and Hall, Ltd., London.

INDEX

A

Accounts, expenses, 289, 294
income, 289, 294
nominal, 293, 295
payable, 293
profit and loss, 298
proprietorship, 289, 294, 295
real, 295
receivable, 290, 292-293
Acetylmethylcarbinol, 112, 118
Acid, coagulation of milk by, 70, 112, 176-177, 225
butyric, 113
caproic, 113
casein, 176, 232, 234-236
for making casein, 236
hydrochloric, 86, 236
hypochlorous, 86, 87
lactic, 81, 82, 93, 97, 112, 177, 178
linoleic, 65
oleic, 65, 97
phosphoric, 236
sulphuric, 75, 84, 236
Acidity, of butter, 97
natural, 81, 89
of cheese whey, 241
of milk, developed, 81
titratable, 81-83, 188, 239
Adrenals, 40
Adulteration, detection of, 80, 83
of milk, 80, 83, 301, 302, 307
Aeration, 174-175
Agar agar, 244
Age affects composition of milk, 54
Agglutination of proteins, 175
Aging the ice cream mix, 246
Agitation, 171-174, 220
of cheese curd, 240
purpose of, 171
Ahmedabad Co-op. Ghee Society, 314-315
Ahmedabad Milk Bazaar, 311
Air, a source of bacteria, 110
Albumen, 46, 55, 66, 70, 88, 113
effect of heat on, 88-89
Alcohol, coagulation of milk by, 63, 176
amyl, 75
test, 176
Alkaligenes viscosus, 113
Allahabad Agricultural Institute, 45, 54, 73, 262, 264, 288, 314
Allahabad Co-op. Milk Supply Union, Ltd., 319
Allegheny metal, 102
Alternaria, 115
Aluminium, 101, 103
Alveoli, 38, 42
Amino acids, 66, 113, 178
hystidine, 67
lysine, 67
tryptophane, 67
Ammonia, 113, 166, 178
compressor, 292
properties of, 166
Amritmahal breed, 2, 271
Analysis, of butter, 95-99
of ghee, 99-101
Area per bullock, 5
Arrow root flour in *gulábjámun*, 229
Artificial, insemination, 35
nursing, 19, 21
respiration, 18
Ascorbic acid, 69
Ash, 46, 53, 55, 56, 74, 88
decomposition by bacteria, 112
nutritive properties of, 68
Ass, 325
milk of, 52
number of, 321
production of, 327
Assets, 289, 290-293
Associative action of bacteria, 111
Atmospheric pressure, 158
Autoclave, 143-144, 165
Ayreshire breed, milk of, 56

B

Babcock, Dr. S. M., 75
Bacillus, 106
Bacillus coli commune, 59
Bacteria, 104-126
associative action of, 111
chromogenic, 107
cryophilic, 106

Bacteria, decomposition of milk by, 112
gas forming, 107
growth phases of, 108
haemolytic, 110
in milk, 104, 109-112, 112-116
in milk products, 116-120
lipolytic, 107, 113
mesophilic, 106
methods of counting, 121-126
motile, 107
nonpathogenic, 106
occurrence of, 107-108
pathogenic, 106, 162
proteolytic, 107, 119
psycrophilic, 121
reproduction of, 104-105
thermoduric, 106, 121
thermophilic, 106, 121
Bacterial, plate count, 124-125
contamination of milk, 109-112, 189, 305
Bactericidal action of milk, 116
Bacteriology of milk, 104-126
Bacterium, 106
Baking soda, 192
Balance sheet, 299
Balances, 152
Bandal cheese, 242, 243
Barafi, 223, 229
Bar-Bari goat, 324
Barn, 14, 17
milking, 18, 127-131
Batch pasteurizer, 145
Bazaar, milk, 311
B. coli, 106, 245
B. cyanogenus, 115
Beestings, 58
Beetle goat, 324
Bicycle, 307, 308
Birds, 142
Bleaching powder (*see* chlorinated lime)
Blood, cells in milk, 47
composition of, 46
plasma, 46
Body cells in milk, 47
Body growth, food energy for, 254
Boilers, depreciation on, 291
capacity of, 145
steam, 139, 144-145
types, 144
Boiling of milk, 163
for *dahi*, 196
Boiling point, of milk, 158, 163
of a solution, 158
Bonds payable, 293
Bones, value of, 3
Bookkeeping, dairy, 289-299
double-entry, 294-299
Bos bubalus, 1
Bos indicus, 1
Bos taurus, 9
Bottle, cappers, 155
fillers, 155
Bottles, 155
Branding, 24
Brass, 101
Breed, choice of, 278
Breeding, records, 256, 269
milking cows, 31
young animals, 26, 28
Breed method of counting bacteria, 125-126
Breeds, draught, 3
dual purpose, 3
milk, 3
of buffaloes, 3
of zebus, 3
Brine, 167
Bronze, 101
B. subtilis, 106, 113
B. synzanthus, 115
B. T. U., 157, 159
Buckets, 151
Budding of yeasts, 105
Buffalo, 1, 3
breeds, 2
composition of milk of, 55, 74
distribution of, 53
milk, 55, 74, 303
number of, 1, 4
producing efficiency of, 278
production of, 268-272, 300
river type, 3
swamp type, 3
Buildings, 127-132, 138-142, 277-278, 290
depreciation on, 292
Bullock, cart, 307, 309
area cultivated by, 5
cost of, 6
cost of maintaining, 5

length of working life, 6
number of, 5
Bulls, exercising of, 34
importance of, 279
management of, 33-35
number of services from, 34
producing potentiality, 14
Burnpur Co-op. Dairy, 316
Business, dairy, 276-286
Butter, 207-218
analysis of, 95-99
bacteriology of, 118-119
breaking stage, 214
churning, 172, 203, 212-215
cold storage of, 168, 217-218
cream procurement, 207-210
culture, 112, 118-119
factory, 73, 74, 207
flavour and aroma, 114, 212
granules, 214-215
keeping quality of, 217
kinds of, 207
Kohman method of analysis, 98-99
marketing, 216-218
moisture control, 216
neutralizing cream for, 93-95, 210-211
outturn, 285-286
paper, 217
preparation of churn, 212-213
price of, 285-286
producing areas, 207
ripening the cream, 211-212
village, 73, 196, 203, 207
washing of, 215
working of, 215-216
Butter fat, 53, 54, 55, 56, 58, 59, 61, 65, 74
calorific value of, 65
cost of production of, 8
decomposition by bacteria, 112
determination of, 75-78
digestibility of, 65, 188
globules, 65
hard, 62
nutritive properties of, 65
precursors of, 46
rising in milk, 179-181, 187, 188
soft, 62
specific gravity of, 180
Butter milk, 68, 73, 74, 76, 213, 215, 285
condensed, 73, 74
dried, 73, 74
uses of, 215, 285
Byramji Dairy, 321-322

C

Calcium, 57, 63, 67, 89
carbonate, 86
caseinate, 66, 70, 176, 177, 178
chloride, 86, 90, 177
citrate, 68
hydrogen phosphate, 70
hydroxide, 93
lactate, 93, 176, 178
oxide, 55, 63, 93
paracaseinate, 177, 178
phosphate, 177
phosphorus ratio, 59, 63, 89
Calcutta Co-op. Milk Union, Ltd., 318-319, 320
Calories, 65, 66, 67, 74, 159
in milk and milk products, 72, 74
Calorific value, 64, 72, 74
of butter fat, 65
of lactose, 66
of protein, 67
Calves, 16, 18-25
care of, at birth, 18
general management of, 22-25
methods of feeding, 19-22
stimulate milk secretion, 42, 45
Calving, interval, 12
stalls, 28, 132
Camel, 326-327
cheese, 326
distribution of, 53
milk, 52
number of, 323
production of, 326
Cans, 151
depreciation on, 292
Cap, bottle, 156
Capacity of the udder, 47
Capital invested in dairy business, 277-281, 290
interest on, 290-291
Carbohydrates, 53
Carbon dioxide, 71, 81, 112, 166, 174
Carica papaya, 237

Carnation Ormsby Madcap Fayne, 268
Carotene, 47, 63
Cartons for butter, 217
Casein, 46, 55, 57, 73, 81, 113, 176, 178, 232-236
  acid, 176, 232, 234-236
  commercial acid, 176
  defects, 234
  drying, 233-234
  edible, 225
  effect of heat on, 89
  grain curd, 236
  isoelectric point, 176, 188
  marketing of, 234
  rennet, 233-234
  types, 232-233, 236
  uses, 234
  yield, 233
Caseoses, 178
Castration of bull calves, 27
Cat milk, 52
Catalase, 60
Cations, 177
Cattle, depreciation on, 292
  labour, 4-7
  management of dairy, 11-35
  population, 1
Caustic soda, 192
Cereal flour, 244
Cereals in *khir*, 223
Chaff cutters, 137-138
Cheddar cheese, 238, 239-242
  adding rennet, 240
  agitating the curd, 240
  amount of salt, 241
  cheddaring process, 241
  cooking the curd, 241
  cutting the curd, 240
  milling the curd, 241
  outturn from milk, 286
  paraffining, 242
  pressing, 242
  price, 286
  removing the whey, 241
  rind formation, 242
  ripening the milk, 239
Cheese, 73, 175, 236-243
  amount imported, 236
  bacteria in, 119-120
  Bandal, 242, 243
  camel milk, 326
  Camembert, 120
  Cheddar, 74, 119, 238, 239-242
  cold storage of, 168
  Cottage, 73
  Cream, 73, 238
  curing of, 119, 237, 242
  Dacca, 242, 243
  Edam, 238
  goat milk, 325
  Neufchatel, 225
  producing areas, 236
  quality of milk required, 237, 238-239
  ripening of, 178
  Roquefort, 238
  soft types, 238, 242-243
  Surati, 238, 242-243
  varieties of, 237
  vegetable rennet for, 237
Chemical sterilization, 193-195
Cherry, 268
Chest, steam, 143, 165
Chháchh, (*see maṭṭhá*)
Chenná, 71, 73, 74, 175, 223, 225-228
  bacteria in, 117
  coagulating agents, 175, 226
  cold storage of, 168
  composition of, 74, 225
  food value of whey from, 228
  marketing, 227
  methods of preparation, 227
  texture, 226-227
  use in sweets, 228, 230-231
  yield, 226
Chloramine-T, 194
Chlorides, 67
Chlorinated lime, 86, 87
Chlorine, 55, 57, 193
  gas, 86, 87-88
  solution, preparation of, 86-88, 194
  sterilization, 86-88, 193-195, 213
Choice of a breed, 278-279
Choline, 115
Chrome-nickel steel, 102
Chromium, 101, 103
Churn, 153-155
  capacity, 153
  cleaning, 212-213
  depreciation on, 292

metal, 153
preparation, 212-213
wooden, 153, 212
Churning, 172, 203, 209, 212-215
break water, 214
breaking stage, 214
butter granules, 214
losses, 214
moisture control, 216
overchurning, 214
overworking butter, 216
temperature, 212
theory of, 213
Citrates in milk, 70, 80,118
Citric acid, 63, 68, 72, 118, 225
Citrus fruit juice, 72, 225
Clarification of milk, 186
Clostridium welchii, 113
Club of India, 7,500 Lb. Buffalo, 272
10,000 Lb. Milk, 272
Clumping of fat globules, 173, 188-189
Coagulation of milk, 88-91, 175-178
by acid, 70, 112, 176-177, 225
by alcohol, 63, 176
by enzymes, 177-178
by heat, 70, 88-91, 175-176
by rennet, 70
Cocci, 106
Coil pasteurizer, 146
Cold storage, of butter, 168, 217-218
of ice cream, 168, 246-247
rooms, 149-150
temperatures, 168
Collecting system of udder, 37, 38, 42
Colour fermentations, 115-116
black, 115
blue, 115
brown, 115
green, 115
red, 115
yellow, 115
white, 115
Colostrum, 19, 58, 88, 176
composition of, 59
Colloidal, emulsion, 65
suspension, 66
Combined churn and worker, 153-154
Common dairy processes, 157-195
aeration, 174-175
agitation, 171-174
chemical sterilization, 193-195
clarification, 186
coagulation, 175-178
heating and cooling, 157-169
homogenization, 187-189
regenerative heating and cooling, 170-171
separation of milk, 179-186
straining and filtering, 179
washing, 189-193
Common measure of producing capacity, 259
Composition, of blood, 46
of ice cream, 74, 243-244, 247
of milk, 46, 52, 53-68, 74
Compressor, 139, 166, 292
Concentrates, 23
Condensed milk, 73, 168, 223, 225, 248-249
texture of, 92, 248-249
Condenser, 139, 166
Condition affects composition of milk, 54
Conditioned reflexes in milk secretion, 42
Constituents of milk, 51-74
Consumer's co-operatives, 316-317
Ahmedabad Co-op. Ghee Society, 316-317
Burnpur Co-op. Dairy, 316
Contamination, of *khoá*, 222
of milk, 109-112, 189, 307
Control Society, 258
Cooking, 164, 241
Coolers, 150-151
Cooling, 166-169
cold storage, 167-168
ice, 168-169
mechanical refrigerating systems, 166, 167, 207
tap water, 169
Cooling and heating, 157-171
heat transfer, 159, 171, 173, 221
physical principles of, 157-158
units of heat, 159-160
Co-operative dairying, 315-322
consumer's co-operatives, 316-317
distributor's co-operatives, 316 317-318
producer's co-operatives, 316, 318-322
reasons for slow progress, 316

Co-operative, Department, United
Provinces, 320
Societies Act, 315, 318
Copper, 67, 102, 103
Cork insulation, 149
Corpus luteum, 40, 41
Corticosterone, 41
Cortilactin, 41
Cost, of handling milk, 288
of milk production, 286-288
Cover-top milking pails, 152
Cow at parturition, 28-29
testing association, 258
working, 6
Cream, acidity for butter making, 209, 211
cheese, 73, 238
cold storage of, 168
composition, 74
determination of fat in, 77-78
effect of heat on, 70
Cream, fat per cent of, 74, 203
line, 69
market, 73
method of ghee making, 203-204
neutralization of, 93-95, 210-211
outturn from milk, 285
preparation of, 209-210
procurement, 207-210
purchase of cream, 208
purchase of milk, 208-209
ripening of, 211-212
separator, 148-149, 182-186, 207
Creamery or milk plant, 138-142
arrangement of rooms, 138-141
floors, 141-142
ventilation, 142
walls, 142
Credit sales, 281
Cross-bred cows, 9, 271, 287
Jersey-Sindhi, 278, 287
Crude protein, 55
Cryoscope, Hortvet, 84, 92
Crystal size, 92
Crystallization, 91-93
Culture, butter, 112, 118-119
dry, 197
milk, 197-198, 238-239
Curd, 67, 112
character of goat milk, 324-325
content of butter, 97
firm, 67
soft, 67
sweet, 113
tension, 67, 187, 188
Current of electric fence, 137
Customer, employees of, 282
Cutch goat, 324
Cycle, 307, 308
vendors, 311

D

Dacca cheese, 242, 243
Dahi, 73, 74, 119, 120, 196-200, 284
amount of starter for, 198
bacteria in, 116-117
coagulation of milk for, 175
contamination of, 199
defects in, 199-200
importance of, 196
incubation of milk, 197
inoculation of milk, 197-198
keeping quality of, 199
kind of starter, 198
lassi from, 200
marketing of, 198-199
pasteurization of milk for, 164
procedure for making, 196-199
rikhand from, 200
sterilization of milk, 196, 197
Dairies, 312-315
Government, 314-315
large private, 313-314
small private, 312-313
Dairy bacteriology, 104-126
Dairy bookkeeping, 289-294
assets, 289, 290-293
expense, 289, 294
income, 289, 294
liabilities, 289, 293
proprietorship, 289, 294, 295
system of, 289
Dairy, business, 276-286
buildings, 277-278
herd, 278-279
employees, 282
land, 276-277, 290
market for milk and milk products, 282-286
other capital items, 279-281

Dairy, cattle management of, 11-35
farming, 1-7
Dairy chemistry, 75-103
Dairy cleaner, formula for, 192
Dairy engineering, 127-156
Dairy equipment, 280, 292
Dairy herd improvement association, 258
Dairying, co-operative, 315-322
Damani sheep, 325
Debits, 295
Defects, in casein, 234
in *dahí*, 199-200
in ghee, 204-206
in ice cream, 246-247
in *khir*, 224
Dehorning, 23-24
De Laval, Dr. Gustav, 148
Delivery of milk, time for, 305-306
Demand for milk, 273-276
characteristics of an elastic demand, 274
converting a need into a demand, 275
is elastic, 273-275
Denaturing of proteins, 69, 175
Denmark, 258
Deoni breed, 2, 271
Depreciation, 291-292
Developed acidity in milk, 81
Diacetyl, 112, 118, 119
Di-calcium phosphate, 176, 178
Digestibility, increased by homogenization, 188
of butter fat, 65, 188
of lactose, 66
of proteins, 67, 70
Direct microscopic method of counting bacteria, 125-126
Disk, bottle, 126
Distributor's co-operatives, 316, 317-318
Radha Swami Educational Institution Dairy, 317-318
Do pyáz, 223
Dog milk, 52
Double-entry bookkeeping, 294-299
balance sheet, 299
definition of, 295
further suggestions, 299
journal, 297
ledger, 297
operation of, 295
possible transactions, 296
posting, 298
profit and loss account, 298-299
trial balance, 298
Double roll churn, 153
Drainage, of creamery floor, 141-142
of paddocks, 15
Draught breeds, 3
Dried milk, 74, 249-250
cold storage of, 168
Dried whey, 73
Drinking water, 16, 17, 33
Driving the cow to the customer, 307
Drum cooler, 151
Drum heaters, 147
Dry animal, management of, 32-33
Dry period, length of, 31-32
Drying, of milk, 164
off the cow, 61
Dual purpose breeds, 3
Dung cake fuel, 201
Dutch breed, milk of, 56

E

Earthenware utensils, 151, 223
Economics of dairying, 273-289
cost of milk production, 286-289
dairy business, 276-286
demand for milk, 273-276
Edward Keventer, Ltd., 313-314
Efficiency of milk production, 9, 11, 275, 278
Eh, 122
Ejection of milk from the udder, 42, 43, 49, 109
Ekká, 307, 308
Elastic demand, 273-275
Electric, equipment, 292
fence, 137
motors, 292
Electroylsis of salt, 86, 87
Elephant milk, 52
Employees, 275, 282
of the customer, 282
requirements, 282
Emulsification of fat, 173

End-over-end churn, 153
Engines, steam, 292
Enterotoxins in milk, 110
Enzyme, 60, 90, 104, 113, 188
coagulation of milk by, 177-178
Epithelial cells in milk, 47
Equipment, dairy, 280, 290, 292
depreciation on, 292
electric, 292
for obtaining production records, 262-268
for washroom, 143-144
laboratory, 292
machine shop, 292
Equivalent weight, 82, 93
Evaporated milk, 73, 223, 248-249
cold storage of, 168
manufacture of, 248-249
sterilization of, 162
Evaporator, 166
Exercise, 15, 34
affects composition of milk, 57
for the bull, 34
Expansion valve, 167
Expenses, 289, 294

F

Factory, butter, 73, 74, 207
method of ghee making, 203
Farm, holding, 4
machinery, 292
Fat globule, clumps, 173, 188-189
membrane, 188, 204, 213
size, 187, 213
Fatty acids, 65
Feed, affects composition of milk, 61-64
records, 257
Feeding schedule, for calves, 22
cow or heifer at parturition, 28
dry cow, 32
milking cow, 30
pregnant animal, 27
young animal, 26
Feed store, 132-133
Fences, 136-137
Fermented milk, 73
Fibre, use of casein for, 73
Film renewal in heat transfer, 159, 173
Filtering milk, 179
Fission, 104
Flash pasteurization, 146-148, 164
Flavour, acid, 112
bitter, 114
caramel, 69
charred, 205, 219
cooked, 69
dung cake, 204
feed and weed, 114, 174
fishy, 114, 115
in butter, 114, 211
in cream, 209
in ice cream, 244
metallic, 114
of milk, 60, 81, 101, 112
oily, 205
rancid, 114
scorched, 114
Flies, 142
a source of bacteria, 110
Floor, drainage, 141-142
in creamery, 141
in milking barn, 128-129
Flue tube boiler, 144
Food, adulteration, acts, 302-305
Food energy value, of goat milk, 325
of milk, affect of heat on, 70
demands in the dairy cow, 254-255
Food poisoning, 110
Fore milk, 61
Forewarming, 90
Formalin, 264
Freezers, ice cream, 246, 248
Freezing, ice cream, 246
kulafi, 248
point, definition of, 83-84
of milk, 55, 57, 83-85, 158
of solutions, 158
preservation by quick, 92
Friesian breed, milk of, 56
Fruit juices, citrus, 72, 225
F. S. H., 40
Funds, retirement or provident, 293
Fungi, 104
Furniture, office, 292

G

Galactose, 46
Galvanized iron, 101

Gas, in milk and milk products, 112
lines, depreciation on, 292
produced by bacteria, 174
refrigeration, 166-167
Gelatin, 244
Genes, 12, 13
Genetics, 12-13
Gerber, Dr. N., 75
method of fat determination, 75-78
Germicidal properties of chlorine, 86
of milk, 116
of oxygen, 86
Gestation period, 12
Ghee, 68, 73, 74, 200-206
analysis of, 99-101
bacteria in, 117
cold storage of, 168
effect of rapid cooling on texture of, 92
from sheep milk, 326
grains in, 91, 202
green, 205
making, 201-204
cream method, 203-204
factory butter method, 203
village method, 201-202
price, 284
production, 200-201
quality, 201, 204-206
raw, 205
sediment in, 206
yellow, 205
Gir, breed, 2, 271
milk of, 56
Gland mammary, 36-39, 41
pituitary, 40, 42
Globules of butter fat, 65
clumps of, 70
Globulin, 46, 70, 88
Glucose, 46
Glue from casein, 73
Goats, breeds of, 324
distribution of, 53
milk, 52, 53, 324-325
number of, 323
production of, 300, 323, 324
Gosále, 300, 310
Government Cattle Farm, Hosur, 315
Grain, 23
Grass, 23
Gravity, flow bottle fillers, 156
separation of milk, 181-182
Grazing area, 17
Grinders, 137-138
Gross efficiency, 256
Gulábjámun, 223, 229-230
preparation of, 229-230
Gum, 244
Guṛ, 228, 244

H

Haemoglobin, 46
Halwái, 223, 310, 311
Hand-drawn milk, 259, 260
Hand, load, 307-308
milking, 45
Hansen, Mrs. Frederick, 258
Hardening ice cream, 246-247
Hariana, breed, 2, 271, 272
milk of, 56
Harness, depreciation on, 292
Head load, 307-308
Health affects composition of milk, 57
Heat coagulation of milk, 70, 175-176
point of milk, 88-91
Heat, effect on milk, 69-70, 88-91
energy, 62
conversion as a measure o utility, 255-256
energy requirements in dairy cattle, 254-256
intensity pattern, 221
stability of proteins, 88-91
sterilization of equipment, 164-165
transfer or exchange, 159, 171, 173, 220-221
types of, 157
units of, 157, 159-160
Heating, 160-165
cooking, 164
drying, 164
pasteurization, 69, 90, 107, 162-164
production of steam and hot water, 161-162
sterilization of equipment, 164-165
Heating and cooling, 157-169
cooling, 166-169
heating, 160-165

physical principles involved, 157-158
regenerative, 170-171
Heifer, age at which to breed, 26
breaking to milk, 29
care at parturition, 29
Hides, value of, 3
High-temperature short-time method of pasteurization, 146, 164 (*see also* hot-short pasteurization)
Histidine, 67
History sheet, 267
Holding method of pasteurization, 145, 164
Holstein-Sindhi milk, 55
Home made ice cream, 247
composition of, 247
Homogenization, of milk, 187-189
of ice cream mix, 246
temperature, 187
Homogenizer, construction of, 189
use of, 189
Honesty of employees, 282
Hoods, paper bottle, 156
Hormones, 39-41, 42
lactogenic, 40-41
mammogenic, 40
oestrogenic, 40
Horses, depreciation on, 292
Hortvet cryoscope, 84, 92
Hot milk, transportation of, 306
Hot-short method of pasteurization, 146-148, 164
Hot water, production of, 161-162
Human milk, 52
Hydrogen ion concentration, 176
Hydrometer, 78
Hyphae of moulds, 105
Hypocalcemia, 30
Hypochlorite, 86, 194
Hypochlorous acid, 86, 87

I

Ice, 168-169
and salt mixtures, 248
Ice cream, 73, 74, 91, 243-248
aging the mix, 246
bacteria in, 120
churning of fat in, 173
cold storage, 168, 246-247
composition, 74, 244, 247
defects in, 247
effect of rapid cooling on texture of, 92
flavours, 244
freezing, 246
hardening, 246
home made, 247-248
overrun in, 246
processing the mix, 244-246
producing areas, 243
quantity of milk used, 243
sources of constitution, 243-244
stabilizers, 244
texture, 247
Ice formation, 91
Ice tanks and cans, depreciation on, 292
Imperial Council of Agricultural Research, 259, 270, 272
Imperial Institute of Agricultural Research, 314-315
Importance of the bull, 279
Income, 289, 294
Incubation of milk for *dahi*, 197
Indian Council of Agricultural Research, 1, 54
Indian Dairy Institute, 314
Indian Farming, 272
Individuality affects milk composition, 57
Inheritance, 12-13
of need for the calf to stimulate milk flow, 42, 45
Inocluation of milk for *dahi*, 197, 198
Insemination, artificial, 35
Insulation, 150
Interest on capital, 290-291
Inventories, 290
Investment of capital in dairy business, 276-281
Iodine, 63, 64, 67, 70
Iron, 67, 102
Isoelectric point of casein, 176, 188
Isotonic, blood and milk are, 48

J

Jersey breed, milk of, 56
Jersey-Sindhi crossbred cows, 278, 287

Jet, steam, 144, 165
Journal, 297
Jumnapari goat, 324
Junket, 177

K

Kankrej, breed, 2, 271, 272
 milk of, 56
Karāhi, 20, 219, 220, 221
Katra Co-op. Dairy, Ltd. 318, 319
Keeping quality, of butter, 217
 of Surati cheese, 243,
Khir, 72, 73, 74, 91, 223-224
 addition of cereals or vegetable, 223
 bacteria in, 117-118
 cold storage of, 168
 defects, 224
 preparation of, 223-224
 quality of, 224
Khoá, 72, 91, 92, 117, 118, 219-223, 285, 300
 agitation of milk, 221-222
 bacteria in, 117-118
 cold storage of, 168
 degree of concentration, 222
 effect of rapid cooling on texture of, 92
 heating the milk, 220
 keeping quality, 222-223
 preparation of, 219-222
 type of fire and stove, 220
Khunti, 222
Kohman method of butter analysis, 98-99
Konradi, Emil, 258
Krishna Valley breed, 2, 271
Kulafi, 78, 91, 248
 effect of rapid cooling on texture of, 92

L

Laboratory equipment, depreciation on, 292
Lactalbumen (*see* albumen)
Lactation, 59
 curve, 261-262
  maximum daily production, 261
  persistency, 262
Lactic acid, 81, 83, 93, 97, 112, 177, 178
Lactobacilli, 112
Lactobacillus acidophilus, 66, 116, 163, 197
Lactobacillus bulgaricus, 116, 197
Lactoflavin, 47, 68
Lactogenic hormones, 40-41
 cortilactin, 41
 galactin, 40
 lactogen, 40
 prolactin, 40
 thyroxin, 41
Lactoglobulin, 46, 113
Lactometer, 78
Lactose, 46, 55, 56, 57, 62, 66, 73, 74, 112, 177
 calorific value of, 66
 carmelization of, 69
 commercial, 66
 decomposition by bacteria, 112
 digestibility of, 66
 properties of, 66
Lamellae, 172
Land, 276-277, 290
Lassi, 73, 74, 200
Latent heat, 157
 of fusion, 91, 157, 159
 of vaporization, 157, 160, 161
Lecithin, 46, 115, 213
Ledger, 297
Le Feldt, Wilhelm, 148
Legal standards, for butter, 216
Legislation, milk, 302-305
Lemon or lime juice, 192
Leucocytes in milk, 47, 110
Liabilities, 289, 293
Lifetime gross efficiency, 256
Lime neutralizers, 93-95, 211
Linoleic acid, 65
Lipase, 188
Lipolysis, 113, 119
Lipolytic bacteria, 107, 113
Llama milk, 52, 53
Loans payable, 292
Location, of milk house, 131
 of milking barn, 131
 of sheds, 135
Lohi sheep, 325
Losses of fat during churning, 214
Lucknow Co-op. Milk Supply Union, Ltd., 288, 319, 320-321

M

Machine milking, 45
Machine shop equipment, depreciation on, 292
Machinery, farm, 292
Madras Co-op. Milk Supply Union, Ltd., 319
Magnesium, 57, 67, 89
  carbonate, 93
  hydroxide, 93
  oxide, 93
Main plant room, 140, 141
Maintenance, food energy for, 254
Makkhan, 72, 73, 117, 196
  (*see also* village butter)
Malái, 73, 74, 224
  (*see also* cream)
Malted milk, 73
Malvi breed, 2, 271
Malwa Creamery, 313
Mammals, 36, 53
Mammary gland, 36-39, 41
  circulatory system, 37, 39, 42
  collecting system, 38, 42
  division, 39
  ducts, 37
  lymphatic system, 37, 39
  nervous system, 37
  secretory system, 37, 42
  tubules, 37
Mammary veins or milk veins, 39
Mammogen, 40
Mammogenic hormones, 40
Management, of the bull, 33-35
  of the calf, 18-25
  of dairy cattle, 11-35
  of the dry animal, 32-33
  of the heifer or cow at parturition, 28-29
  of the milking animal, 30-32
  of the pregnant animal, 27-28
  of the young animal, 25-27
Manganese, 67
Manipulation stimulates milk flow, 43-44
Manure, production of, 10
  value of, 3, 10
Mare Milk, 52
Marketing, of butter, 216-218
  of casein, 234
  of *chhená*, 228
  of *dahí*, 198-199
  of goat milk, 325
  of *khír*, 224
  of *khoá*, 223
  of milk and milk products, 282-286, 300
Marking animals, 24
Mastitis, 57, 110
Maṭṭhá, 72, 73, 74, 196, 206, 284, 300
  food value of, 206
  production of, 72, 206
Maturity, physical, 25
  sexual, 25, 33, 37
Maximum daily production, 261
Meat, value of, 3
Mechanical refrigeration, 166, 167, 207
  principles of, 166
  systems of, 167
Mechanical separator, 182-186, 207
Melting point of butter fat, 65
Metals and milk, 101-103
Methyl chloride, 166
Methylene blue reduction test, 122
Methylene chloride, 166
Micrococci, 106, 109
Micro-organsims, action in milk, 112-116
Middle milk, 60, 61
Military Farms Department, 314
Milk, acidity, developed, 81
    natural, 81, 89
  adulteration, 80, 83, 301, 302, 307
  a human food, 52-53
  and metals, 101-103
  a semi-solid food, 67
  ash, 47, 53, 55, 56, 74, 88
  bacteria in, 104, 109-112, 112-116
  bactericidal action, 116
  bacteriology, 104-126
  bazaar, 311-312
  boiling point, 158, 163
  bottles, 155
  breeds, 2
  buffalo, 53, 74
  butter, 68, 73, 74, 76, 213, 215, 284
  camel, 52
  cistern, 38, 43
  clarification, 186
  classes, 122, 123

cold storage, 168
colour, 69
coagulation, 88-91, 112, 172, 175-178
composition, 46, 52, 53-64, 74
condensed, 73, 168, 223, 225, 248-249
constituents, 51-74
precursors of, 46-47
consumption, 51
cultures, 198, 238-239
definition of, 51
diseases transmitted by, 110
dried, 74, 249-250
effect of heat on, 69-70, 88-91
ejection, 42, 43
enterotoxins in, 110
evaporated, 73, 74, 225, 248-249
factors affecting composition, 54-64
fat, 46, 53
fed to calves, 7
fermented, 73
fever, 30
flavour, 60, 69, 81, 101, 112, 113
food value, 70
for butter making, 207, 282
for cream, 282
for *dahi*, 196, 282
for ghee, 200, 282
for human consumption, 7, 52-53, 282
for ice cream, 243, 282
for *khoá*, 223, 282
for sweets, 228
forewarming, 90
freezing point, 55, 57, 83-85, 158
hand-drawn, 259, 260
heat coagulation point, 188
house, 131, 262
keeping quality, 310
legislation, 302-305
made safe by boiling, 163
malted, 73, 74
market, 73
market for, 7, 282-286
marketing of, 300-315
nutritive properties, 51-74
outturn, of products from, 285-286
oxidation-reduction potential, 122
pasteurization, 162-164
perishability, 275
pigments, 47
plant, 138-142
powder, 249-250 (*see also* dried milk)
preservation by refrigeration, 121
prices, 273, 274, 284
producing efficiency, 9, 11, 275, 278
production, 7-10, 51, 52, 251-272, 282-283, 286-289, 300
products, bacteria in, 116-120
formation of, 73
nutritive value of, 71-74
protein, 46, 66-67
quality, 301-305
for cheese, 237, 238
recording, 258-270
reduction time of, 122
ropy, 113
sanitary condition of, 307
secretion, 36-50
separation of, 179-186
serum, 65
skim, 68, 73, 74, 76
skin formation on, 69, 172, 225
solids-not-fat, 53, 55, 56, 58
solubility of metals in, 70
specific gravity, 78-80, 180
specific heat, 157
standards, 302-305
sterilization, 196, 197
stock, depreciation on, 292
stone, 190
straining and filtering, 179
sugar, 46, 56, 65-66
sweets, 223, 228-231
titratable acidity, 70, 81-83, 176, 210
total solids, 53, 55, 56, 80
transportation, 306-310
use of grass and leaves to prevent spilling, 301
utilization in India, 9, 282
value, 3, 9
veins, 39
vitamins in, 47, 68-69
wells, 39
whole, 73, 74, 75-76
zebu, 53, 74
Milker, a source of bacteria, 110

Milking, animal, management of, 30,32
by hand or machine, 45
frequency of, 30, 49
pail, 152
preparation of the cow for, 31
rapid, 49
should be regular, 30
sources of bacteria, 109-112
wet hand method of, 307
Minerals (*see* ash) 53, 67-68
Miscellaneous fences, 136
Miṭhái, 73
M. niger, 115
Moisture, control in butter, 216
legal standards, 216
Monkeys, 142
Mono-calcium paracaseinate, 178
Mono-calcium phosphate, 176, 178
Montgomery breed, milk of, 56, 59
Mortgages payable, 293
Motor, cars, depreciation on, 292
electric, 292
transport of milk, 306, 309
Moulds, 104, 119, 223
black, 115
blue, 115
green, 120
white, 120
M. roseus, 115
Multiple-roll churn, 153
Murra breed (*see* Murrah breed)
Murrah breed, 2, 271, 272, 287, 315
milk of, 55, 56, 59
Mycelium, 105
Mycobacterium tuberculosis, 107, 163

N

Nascent oxygen, 86, 87, 193
germicidal effect of, 86
Natural acidity of milk, 81, 89
Natural nursing method of calf feeding, 20-21, 259
Need for milk, in India, 275
converting into a demand, 275
Nellore breed, milk of, 56
Nervous control in milk secretion, 41-46
Neutral soda, 192
Neutralizers, 211
Neutralizing cream, 93-95, 210-211
acidity to which reduced, 210
amount of neutralizer to add, 93
how to add neutralizer, 211
objects of, 210
Nickel, 102, 103
Nicotinic acid, 68
Nili breed, 2, 271
Nitrogen, 113, 174
non-protein, 55, 57
Nominal accounts, 293, 295
Notching the ears for identification, 24
Number of milkings, 47-49
Nursing of calves, artificial method, 19, 21
natural method, 19, 20-21, 44
Nutritive properties, goat milk, 324
milk, 51-74
milk constituents, 65-69

O

Oestrogen, 40
Oestrogenic hormones, 40
Oestrus, 31, 40
affects composition of milk, 58
Office furniture, 292
Oidium lactis, 115
Oleic acid, 65, 97
Ongole breed, 2, 271
milk of, 56
Operating fund, 279, 281
Osmosis, 47
Osmotic pressure, 48, 57, 83
Outstanding production records, 268, 270-272
Ovary, 40
Over-all gross efficiency, 256
Overrun in ice cream, 246
Overworking butter, 216
Oxidation-reduction potential, 122
Oxygen, 174
nascent, 86, 87, 193

P

Packet butter, 217
size of packets, 217
Paddocks, 15

Pail feeding calves, 19, 21-22
Pails, 151-152
  construction, 152
  cover-top milking, 152
  depreciation on, 292
Paint, use of casein for, 73, 234
Papaya, a source of vegetable rennet, 237
Paper milk bottles, 156
Parchment paper, 216
Parturition, care of animal at, 28-29
Pasteur, Louis, 162
Pasteurization, 69, 70, 89, 107, 162-164
  definition, 162
  destroys lipase, 188
  exposures, 164
  flash method, 146-148
  hot-short method, 146-148
  methods, 164
  of ice cream mix, 245
  vat or holding method, 145, 164
Pasteurized milk, 73
Pasteurizers, 145-148
  depreciation on, 292
  types, 145
Pathogenic bacteria, 106, 162
Penicillium, 115, 116
  camemberti, 116, 120
  roqueforti, 120
Pepsin, 177
Peptones, 113, 178
Peptonization (*see* proteolysis)
Peptonizing factor in rennet, 178
Perá, 223
Persistency of lactation, 262
pH, 57, 60, 112, 118, 176, 188, 226, 236
Phenolphthalein, 81
Phosphate in milk, 57, 67, 81, 89
Phospholipids, 46
Phosphorus pentoxide, 55
Pigments in milk, 47
Pinjarápol, 300, 310
Pit silo, 133
Pituitary gland, 40
Placenta, 40
Plastics, use of casein for, 73
Plate count, bacterial, 124-125
Plate heaters, 146-147
Plumbing fixtures, 292
Polson, Ltd., 153, 314
Porpoise milk, 52
Posting, 298
Potassium, 57, 67
  dichromate, 192
  di-hydrogen orthophosphate, 68
  thiocyanate, 98
Powdered milk, 73, 249-250
Precursors of milk constituents, 46-47
Pregnant animal, management of, 27-28
Preservatives, acids as, 120-121
Prices, ratios of, 284-286
Private dairies, 312-314
Processing, ice cream mix, 244-246
  aging, 246
  assembling the materials, 244
  calculations, 245
  homogenizing, 245
  pasteurizing the mix, 245
  testing the materials, 245
Producer-distributor, 311
Producer's co-operatives, 316, 318-322
  Allahabad Co-op. Milk Supply Union, Ltd., 319
  Byramji Dairy, 321, 322
  Calcutta Co-op. Milk Union, Ltd., 318-319, 320
  Katra Co-op. Dairy, Ltd., 318, 319
  Lucknow Co-op. Milk Supply Union, Ltd , 288, 319, 320-321
  Madras Co-op. Milk Supply Union, Ltd., 319
  Telankheri Dairy Co-op. Society, 321
Producing, areas, for butter, 207
  for cheese, 236
  for ghee, 283
  for ice cream, 243
  for *khoá*, 283
  capacity, common measure of, 259
  efficiency, 11, 275, 278
  zones for milk, 283
Production, of average farm cow,
    in England, 268
    in India, 268
    in United States, 268
  of butter, 207
  of camel milk, 326-327
  of *dahi*, 196

of ghee, 200-201
of goat milk 300, 323, 324
of milk, 7-10, 251-272, 286-289
of sheep milk, 326
on approved farms, 270-271
records, 251-272
world's record, 268
Profit and loss account, 298-299
Progestin, 40
Proprietorship, 289, 294, 295
Proteins, 46, 55, 56, 57, 62, 66-67, 72, 74
albumen, 46, 55, 66, 70, 88, 113
calorific value, 67
casein, 46, 55, 66
decomposition by bacteria, 112, 113
denatured, 69, 175
digestibility of, 67, 70
globulin, 46, 66, 70
heat stability, 88-91
Proteolysis, 113, 119, 121
Proteolytic bacteria, 107, 119
Proteus ichthyosimus, 115
Provident fund, 292
Ps. cyanagenus, 115
Pseudomonas fluorescens, 113, 114, 115
Pumps, depreciation on, 292
Punjab Agricultural College, 314, 315
Purchasing milk or cream on a butter fat basis, 208-209
advantages of, 208
Pyridoxine, 68

Q

Quality, of *khír*, 224
of *khoá*, 222
of milk for cheese, 237, 238

R

Rabarí, 72, 73, 74, 91, 117, 172, 224-225
bacteria in, 117
cold storage of, 168
preparation, 224-225
Racks, feed, 16
Radha Swami Educational Institution Dairy, 317-318
Rapid milking, 47, 49
Raw milk, 73
Rasagullá, 228, 230
preparation of, 230
Rates of depreciation, 292
Ratio, maximum daily yield: total lactation production, 261
Ration, grain or concentrate, 17
Ratios of price, 284-286
Reasons for maintaining production records, 253-254
Receiving, funnel, 262
platform, 139, 140
Record forms, 264-268, 269
Records, breeding, 256, 269
feeding, 256
of stock, 290
production, 257
Red Sindhi breed, 2, 271, 272, 287, 315
milk of, 55, 56, 59
Reductase test, 122-124
Reduction time of milk, 122
Refractive index, test for, 101
Refrigeration, 121, 149-151, 167-168
gases, 166-167
characteristics of, 167
mechanical, 166, 237
systems, 167
Regenerative heating and cooling, 170-171
Reindeer milk, 52, 53
Rennet, 63, 90, 113, 119, 124, 176, 178, 237
casein, 177, 233-234
use in cheese making, 240
Rennin, 177
action of, 177-178
source of, 177
Reproduction, 12
food energy for, 255
of bacteria, 105
Resazurin-rennet test, 123-124
Resazurin test, 123-124
modified, 123
Reserves, 290, 293
Retirement funds, 293
Retort, steam, 165
Riboflavin, 68
Rinderpest, inoculation for, 27

Ripening, cream for butter making, 211-212
milk for cheese making, 239
Roll process of drying milk, 249
Rolless churn, 155
advantages of, 155
Roof of milking barn, 128
Ropy milk, 113
Rural areas, milk production in, 282-283

S

Sahiwal, 2, 271, 272, 287, 314
Salt, 17
addition to butter and cheese, 216, 241
content of butter, 96-97
and ice mixtures, 248
Sample, bottles, 264
definition, 171
preservative, 264
Sandes, 228, 230-231
preparation, 230-231
Saponification value, test for, 100
Sár, 224
Sarcina, 106
Scales, 152, 262
depreciation on, 292
Scindi breed (*see* Red Sindhi breed)
Scorching, 222
Season affects composition of milk, 64
Secretion of milk, 36-50, 61, 109, 255
osmosis involved in, 48, 49
rate, 47, 49
stimulated, by calf, 42, 44, 45
by manipulation, 42, 43
Secretory cells, 39
Sediment in ghee, 206
Selection of dairy cattle, 14
Selective breeding, 253, 279
Sensible heat, 157, 166
Separated milk (*see* skim milk)
Separation of milk, 179-186
gravity, 181-182
mechanical, 182-186
Separator, 148-149, 182-186, 207
adjustment of cream screw, 184
condition, of machine, 186
milk, 185
construction, 182
factors affecting efficiency, 182-183
method of cleaning, 185
rate of inflow, 183
slime, 185
speed, 183
temperature of milk, 183
Septic sore throat, 110
Services by the bull, 33-34
7,500 Lb. Buffalo Club of India, 272
Sheds, 15, 135-136
Sheep, 325-326
distribution of, 53
milk, 52, 326
ghee from, 326
number of, 323
production of, 325-326
Shorthorn breed, milk of, 56
Silage, 121
weight of, 134
Silo, 132, 133-135
capacity of, 134-135
Silver chloride, 98
Singhal's Dairy, 312
Single-roll churn, 153
Site for a creamery, 138
Size, affects composition of milk, 54
of butter granules, 214
of fat globules, 187, 213
Skim milk, 68, 73, 74, 76
condensed, 73, 74
determination of fat in, 76
dried, 73, 74
evaporated, 74
fat percentage in, 186
possible uses of, 232, 285
Skin on milk, 69, 172, 225
Soap, 192
Soda, ash, 192
lye, 192
neutralizers, 93, 211
Sodium, 51, 67
alginate, 244
bicarbonate, 93, 192
carbonate, 86, 93, 192
chloride, 68, 177, 178
hydroxide, 81, 93, 192
hypochlorite, 86, 87
sesquicarbonate, 192
Soft cheese, 238, 242-243

Solids-not-fat, 53, 55, 56, 58
testing for, 245
Solution, 65
boiling point of, 158
freezing point of, 158
Sour whey, 72
Sources of bacteria in milk, 109-112
external, 110-112
internal, 109-110
Special problems in milk marketing, 305-306
Specific gravity, 55, 78-80, 180
an indication of adulteration, 80
definition, 78
determination, 78-80
of fat, 180
of non-fat fraction, 180
of whole milk, 180
Specific heat, 157
of milk, 158
Spilling of milk, use of grass to prevent, 301
Spores, bacterial, 105, 107
Spray, process of drying milk, 249
jacketed pasteurizer, 145
Spring scale for production records, 262
Śrikhaṇḍ, 200
Stabilizers in ice cream, 244
Stage, of lactation affects composition of milk, 58-60
of milking affects composition of milk, 60-61
Stainless steel, 101
Stalls, calving, 28, 132
feed, 16
Standardizing the microscope, 126
Standards for milk, 302-305
Staphylococci, 106, 110
Staph. aureus, 110
Starter, 73
butter, 112, 118-119
cheese, 239
dahi, 197
Stassiniser, 147
Steam, advantages of, 161
boiler, 139, 144-145
chest, 143, 165
definition of, 161
differs from hot water, 161
Steam, engines, depreciation on, 292
jet, 144, 165
lines, depreciation on, 292
pressure required, 144
production, 161-162
Sterilization, 111, 162, 197
by chlorine, 86-88, 193-195
by heat, 70, 164-165
by smoke, 193
by the sun, 193
chemical, 193-195
of equipment, 164-165, 190, 191, 193, 195
of evaporated milk, 162
of milk for *dahi*, 196, 197
Sterilized milk, 73
Stimulus in milk secretion, 42, 43, 44
Stock, of supplies, 279, 290
of unsold goods, 279, 280, 290
records, 290
Stone, milk, 190
Store room, 140, 141, 149-150
Straining milk, 179
Streptococci, 106
Str. agalactiae, 110
Str. citrovorous, 118
Str. lactis, 112, 115, 116, 118, 120, 177
var. hallandicus, 113
Str. liquefaciens, 112, 119-120, 239
Str. paracitrovorous, 118
Str. thermophilus, 112
Strippings, 61
Successful business, 283
Sūji, 230
Sulphur dioxide, 166
Sulphuric, acid, 75, 84, 236
Supplementary records, 256-258
Supplies, stocks of, 279
Surati cheese, 238, 242
keeping quality, 243
method of manufacture, 242
yield, 243
Surface, cooler, 150
film renewal in heat transfer, 159
Surti, buffalo, 2, 271
milk of, 56
goat, 324
Sweet curd, 113
Sweet curdlers, 90, 198
Sweetened condensed milk, 225
Sweets, 223, 228-231
barafi, 223, 229
general description, 228

gulábjámun, 223, 229
made from *chhená*, 230-231
made from *khoá*, 228-230
making, an art, 228
peṛá, 223
rabaṛi, 225, 228
rasagullá, 228, 230
sandeś, 228, 230
Symbiosis, 111

T

Tanks, wash, 143
water, 16
depreciation on, 292
Tatooing, 24
Teat, 38
sphincter muscle of, 43
Telankheri Dairy Co-op. Society, 320
Temperature, defined, 158
gradient and heat transfer, 159
of ice and salt mixtures, 248
of tap water, 161-162
-time treatments, 88, 107, 162, 163, 164, 165
Temperatures, classification of, 160
cold storage, 168
10,000 Lb. Milk Club of India, 272
Test, alcohol, 176
butter fat, 207, 245
for acidity in butter, 97
for adulteration of milk, 80, 85
for contagious abortion, 32
for curd and salt in butter, 96-99
for fat by the Gerber method, 73-78
for fat in butter, 97, 99
for freezing point of milk, 83-85
for Johne's disease, 32
for moisture, in butter, 96, 98-99
in ghee, 100
for purity of milk, 313
for refractive index of butter fat, 101
for saponification value of butter fat, 100
for specific gravity of milk, 78-80
for titratable acidity of milk, 81-83
for total solids of milk, 80
for tuberculosis, 32
reductase, 122-124
Tetracocci, 106
Texture, effect of rapid cooling on, 92
of condensed milk, 92, 249
of ice cream, 247
Tharparkar breed, 2, 271
milk of, 56
Thermal, conductivity and heat transfer, 159
death point, 163
Thyroid, 40
Tilsit cheese, 326
Tin, 101, 102, 103
Tinned butter, 217
method of tinning, 217, 218
size of tins, 217
Titratable acidity, 70, 81-83, 177, 188, 210, 239
determination of, 81-83
Tonga, 307, 308
Total solids, 53, 55, 56
determination of, 80
Tonic salts, 101
Train transport of milk, 307, 309-310
Transactions in double-entry book-keeping, 295-296
Transportation of milk, 306-310
bicycle, 307, 308
bullock cart, 307, 309
ekká, 307, 308
head load, 307-308
motor, 307, 309
open pail, 301
tonga, 307, 308
train, 307, 309
Trench silo, 133
Trial balance, 298
Trimethylamine, 115
Tri-sodium phosphate, 192
True protein, 55
Tubular heaters, 147
2, 3 butylene glycol, 118, 119
Typewriters, 292

U

Udder (*see also* mammary gland), a source of bacteria, 109-110

a source of leucocytes, 109, 110
capacity, 47
engorged or swollen appearance, 38
physical development, 37-39
United Provinces Prevention of Adulteration Act (1912), 205, 302
Units of heat, 159-160
Unsold goods, stock of, 279,
Uses, of butter milk, 215, 285
skim milk, 232
Utensils, 151
a source of contamination, 301
earthenware, 151, 223
washing, 111
Utilization of milk, 9, 283

V

Vacreator, 148, 209
Vacuum, 148, 158
bottle fillers, 156
Value of, bones, 3
cattle labour, 3, 4
cattle manure, 3, 10
hides, 3
livestock exported, 3
meat, 3
milk, 3, 7, 9
production records, 251-272
Vat pasteurization, 145, 164
Vegetable rennet, 237
Vegetables in *khir*, 223
Vendors, cycle, 311
Venedotian measure, 258
Ventilation of, creamery, 142
sheds and barns, 17, 128
Village, buffalo milk, 55
butter, 73, 196, 203, 207
butter milk, 206
zebu milk, 55
Vitamin, A, 62, 68
B, 63, 68
C, 63, 68
D, 63, 68
E, 63, 68
Vitamins, 46, 47, 53, 63, 68-69, 70
decomposition by bacteria, 112
nutritive properties of, 68-69
Volts, 122, 137

W

Wagons, depreciation on, 292
Walls, of creamery, 142
of milking barn, 127-131
Wash room, 139
equipment of, 143-144
Washing, butter, 215
dairy equipment, 111, 189-193
powders, 190-192
procedure for, dairy or creamery, 190-192
soda, 86, 192
village, 192-193
Water, for drinking, 16, 17, 33
in milk, 17, 55, 56, 74
in milk products, 74, 96
tap, temperature of, 162, 169
production of hot, 161-162
Water jacketed pasteurizer, 145
Water tube boiler, 144
Waxed paper, 223
Weaning calves, methods of, 19
Weighing pail, 262
Welch breed, milk of, 56
Wet hand milking, 307
Whey, 68, 73, 74
dried, 73
removal in cheese making, 241
sour, 73, 225
White ants, 111, 131, 135
White blood cells in milk, 47
Whole milk, 68, 73, 74, 75-76
dried, 73, 74
evaporated, 73, 74
Wire fence, 136-137
Withania coagulans, 237
Wood ash, 192
Working, buffaloes, 7
bullocks, 6
cows, 6
of butter, 215-216
World's record milk production, 268

Y

Yeasts, 104, 112, 223
Yield, of casein from skim milk, 233
of Surati cheese, 243
Young animals, age at which to breed, 26, 27, 28
management of, 25-27

Z

Zebu, breeds of, 2
distribution of, 53
milk, 53, 55, 69, 74
standards for, 303
number of, 1, 4
producing efficiency, 278
production, 268, 272, 300
Zinc, 101, 103
Zones of milk production, 282